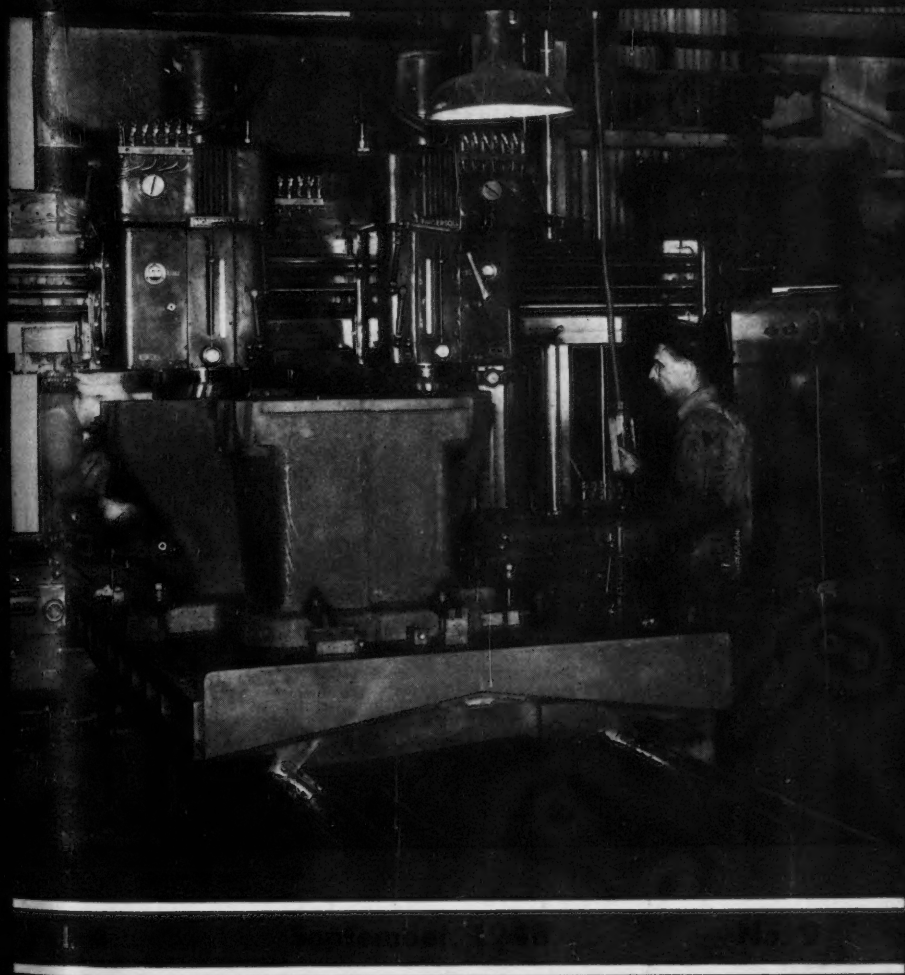


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AMERICAN ASSOCIATION OF CORROSION ENGINEERS





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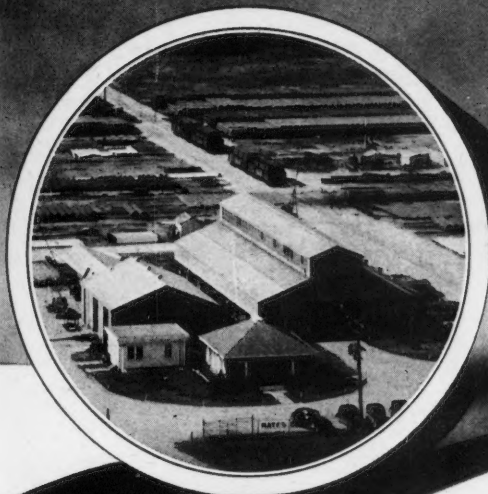


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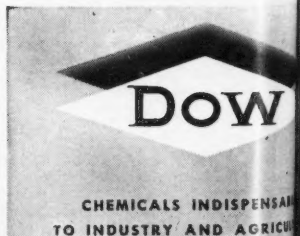
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Corrosion

devoted entirely to

CORROSION

Research and Control

PUBLISHED MONTHLY AS ITS OFFICIAL JOURNAL, BY THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS, INC., AT HOUSTON, TEXAS. U. S. A., TO PROVIDE A PERMANENT RECORD OF PROGRESS IN THE CONTROL OF CORROSION AS DESCRIBED IN PAPERS PREPARED FOR THE ASSOCIATION AND FROM OTHER SOURCES.



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THIS MONTH'S COVER

• Finishing a gear housing joint surface on a planer type milling machine in the Machine Shop of Lufkin Foundry & Machine Co., Lufkin, Texas. Other than the usual corrosion preventive maintenance exercised in the plant, Lufkin, like others in the industry, is vitally concerned with prevention of corrosion on accurately machined, highly polished surfaces on products during handling, shipping and storage.

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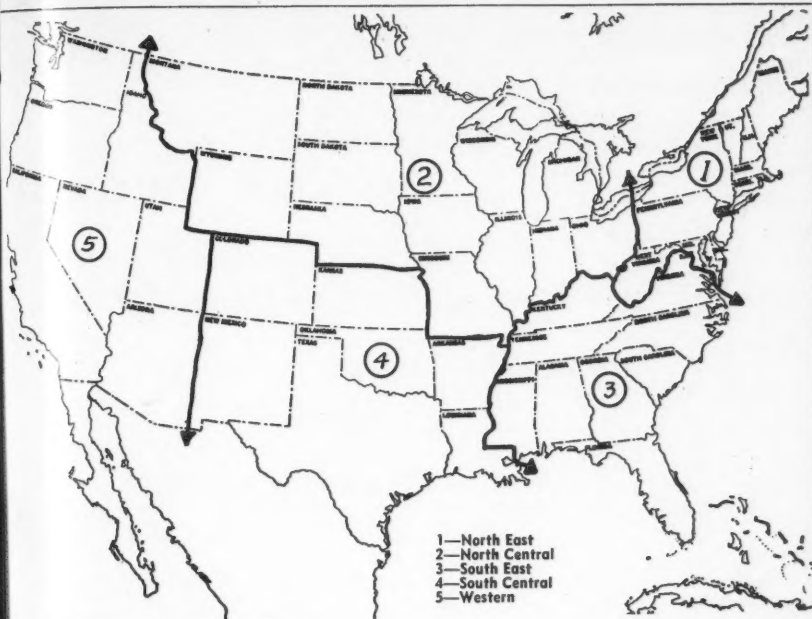
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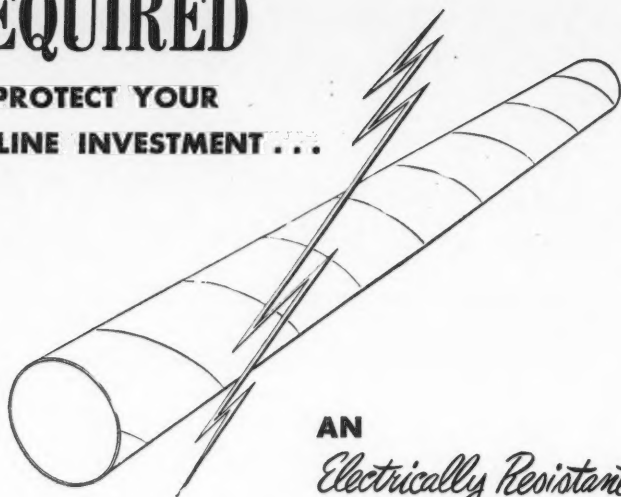
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A Message from Your Officers

By JOHN M. PEARSON,

Director Representing Corporate Membership



ONE who is engaged in research is working first to define, then to measure and understand some part of nature. This implies experiment, observation, deduction, and again experiment. The greatest understanding is achieved when many experimental facts are explained by a few new concepts.

One who is engaged in development work is trying to take the fruits of research and reduce them to practice. He can do this in many ways such as by building a new device, by building and testing a new process, or by showing a better way to analyze an old problem in terms of new ideas.

An engineer is one whose job it is to fit technology into an economic background. He must know and understand

the developments upon which his profession depends, and he ought to know the history and research behind those developments. An engineer's vital job is to determine the best technology to apply to his client's problem; then to determine the most economic scale for the application. By "best" is meant that technology most likely to give a satisfactory and economic answer in the present and foreseeable future.

Too many problems in corrosion engineering are those which deal with equipment failures resulting from designs that were inadequate in view of corrosion. Under these conditions the cost of corrosion engineering and of the repairs are an expense to the owner and represent a loss, especially if a shutdown of production is involved.

A corrosion engineer should participate in initial designs with a view to increasing the productivity of each client's investment, and to minimize the cost of corrosion from all angles. To do this the corrosion engineer should seek out and answer his client's \$64 questions before they are raised by circumstance. He should prepare to show his client how to apply the best available technology to his problems and lay before him an economic analysis showing how each proposal will pay out.

Just to the extent that corrosion engineers apply their science to the increase of investment values will they graduate from the maintenance to the engineering department.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.



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Action of Rust-Preventive Oils*

By E. R. Barnum,* R. G. Larsen* and A. Wachter*

RUSTING of iron and ferrous alloys has been a problem for centuries. Paints have been long employed as protective coatings while grease and petrolatum have been used extensively to provide protection when removable coatings were required. Oil films, which are much easier to apply and remove, were inadequate for this purpose until it was found that their rust-proofing efficacy could be greatly increased by addition of certain types of polar organic compounds.¹

World War II gave strong impetus to development of such compounded oils for a wide range of service requirements. These oils are used extensively now to provide temporary protection for ferrous metal articles during manufacturing operations, storage and shipment, as well as for protection and lubrication of machinery, guns, turbines and hydraulic systems.¹

The urgency of military needs during World War II was largely responsible for the adoption of empirical methods in development of protective oils. This article presents research undertaken to reveal the mechanism by which polar compounds impart rust-preventing qualities to oils.

Basic Function of Protective Oils

Since water must be present to enable the reactions of atmospheric corrosion to occur, it follows that rusting can be prevented if moisture which may be on the steel surface is removed and no further access permitted. To achieve protection of steel by exclusion of oxygen is impractical because of the relatively high solubility of oxygen in hydrocarbons.

Although hydrocarbon oils do not provide effective rust-preventive films, this property is acquired by addition of certain polar organic compounds (polarity meaning that a separation of electric charges, or dipole, is present in the molecule). When steel is in contact with a rust-preventive oil, the polar compounds are adsorbed in oriented layers at the steel-oil interface to form a semirigid lattice containing oil. The combination of oil and polar compound hinders the ingress of moisture to the steel surface. Evidence for this basic explanation is presented below.

Adsorption of Polar Compounds on Steel

Other investigators have shown that, when a homogeneous oil solution of polar additives contacts a metal surface, the additives are concentrated at the metal-oil interface.^{2,3} It therefore seems reason-

* A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

* Shell Development Co., Emeryville, Calif.

able that adsorption would play an important part in determining the behavior on steel of oils containing polar compounds. Hence quantitative adsorption studies were made of different types of polar compounds, some of which had proved to be effective additives in oil.

Adsorption was determined by stirring a weighed amount of iron powder with a solution of organic compound in a highly refined mineral oil for one hour at 30° C. and then filtering off the iron powder. The amount of additive removed by adsorption on the iron was calculated from the decrease in concentration in the oil. This was measured by observing the change in interfacial tension (between oil and water), which is very sensitive to concentration of polar additives in the oil, and comparing the observed value with a calibration curve (Figure 1). Interfacial tension was measured with a du Noüy interfacial tensiometer. Since significant increase in interfacial tension with time occurred for some oil solutions, variations due to this factor were minimized by aging all oil solutions for at least 16 hours at 30° C. before measurement.

By measuring adsorption at various additive concentrations and plotting the adsorbed quantity as a function of additive concentration, three general types of adsorption curves (isotherms) were obtained (Figure 2). The surface area of the

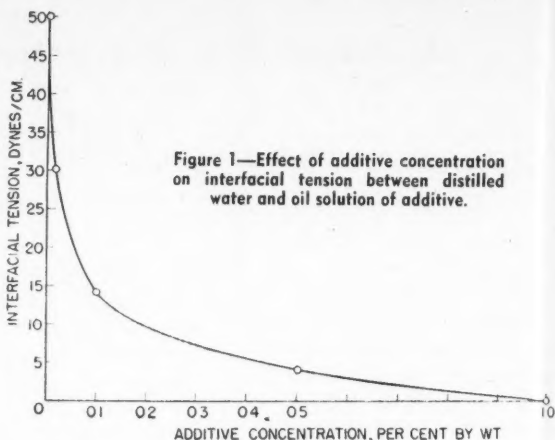


Figure 1—Effect of additive concentration on interfacial tension between distilled water and oil solution of additive.

iron powder was determined by adsorption of nitrogen on the powder according to the method described by Brunauer, Emmett and Teller.⁴ From the surface area, it was calculated that compounds of Type III are adsorbed to a maximum thickness of 1 or 2 molecular layers, while the more highly adsorbed compounds represented by Curves I and II gave layers several molecules thick. Although the exact number of the latter could not be determined because the maximum degree of adsorption could not be established by the method used, it is obviously considerably greater than 1 or 2 molecular layers.

All of the additives that showed a high degree of adsorption, illustrated by isotherms of Types I and II, were good rust inhibitors, while the additives showing low adsorption, exemplified by Type III, were poor. Since only one additive was examined that gave the Type II curve, no correlation can be made concerning the shape of the adsorption curves and rust-proofing effi-

cacy of the additive involved. However, the relationship between the extent of adsorption and rust protection indicates that a multilayer, rather than a monomolecular layer, of rust-preventive additive on the steel surface is required for good rust protection.

Multimolecular Surface Films

Further evidence on the importance of multimolecular adsorption was found in a study of "built-up" films on steel surfaces. By means of a technique similar to that described by Blodgett,⁵ films of a known number of molecular layers of polar compounds on steel were prepared as follows: An oriented monomolecular film of the compound was first spread on the surface of distilled water in a trough and then transferred to a polished steel panel by lowering the latter (in a vertical position) beneath the surface of the water and then withdrawing it (Figure 3). As the panel moved through the surface, constant pressure was maintained on the molecular film by means of a film of castor oil separ-

ated from the monomolecular film by a waxed thread. By observing the motion of the thread, the number of monomolecular layers transferred to the steel in repeated immersions could be determined. The number of monomolecular layers and orientation of the additives in these films are summarized in Table I.

Humidity cabinet corrosion tests on films applied in this manner revealed that, with one exception,* they were ineffective in preventing rusting regardless of the number of molecular layers present (Table I). However, some of these polar compounds were known to be effective rust inhibitors when applied in oil solutions. Therefore, humidity cabinet tests were made with steel which had been dipped in oil after first coating with comparable multilayer films. In the presence of oil improved performance was found for certain types of compounds applied as a multimolecular film. It may be noted that even additive E, which provided some protection

alone, was much more effective with oil. No protection was observed for films one or two molecules thick regardless of the type of compound involved. It appears that a minimum of about six molecular layers was required to impart rust protection.

It is recognized that "built-up" films of additives do not neces-

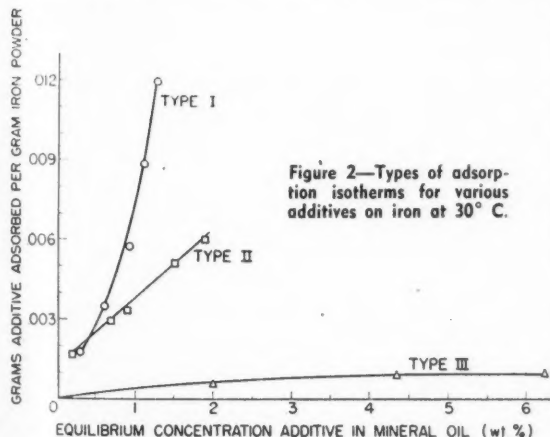
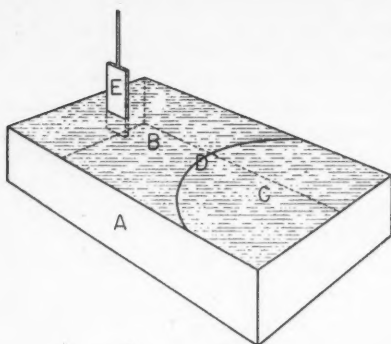


Figure 2—Types of adsorption isotherms for various additives on iron at 30° C.

* Additive E in Table I, which showed much closer packing on steel than any other.



Metal through A is coated on inside with wax. Monomolecular layer of polar compound is designated area B, while area occupied by castor oil is marked C. Curved line D is waxed thread which separates the two. Polished steel panel E is raised and lowered through water surface by a windlass in order to get uniform motion.

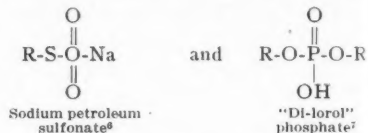
Figure 3—Apparatus for preparing "built-up" surface films.

sarily represent the same type of orientation or degree of adsorption as that produced by direct contact of oil solutions. Hence the same additives were deposited on steel from solutions in a volatile hydrocarbon and after the solvent had evaporated were subjected to humidity cabinet tests. These, like the "built-up" films, were ineffective in preventing rusting (Table I). Thus, in addition

to substantiating the theory that multimolecular adsorption is an important aspect of rust prevention, these results show that oil does not merely provide a medium for placing the additives on the steel but also becomes a part of the protective film.

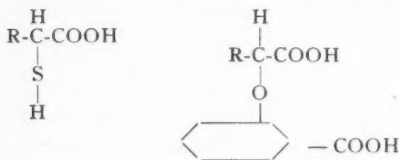
Chemical Structure of Rust-Preventive Additives

Several types of organic compounds may serve as rust inhibitors in mineral oils. All have one characteristic in common, namely, a large hydrocarbon group attached to one or more smaller polar groups. If only one polar group is present, it must have sufficient dipole moment to be highly adsorbed at the steel-oil interface. Compounds such as



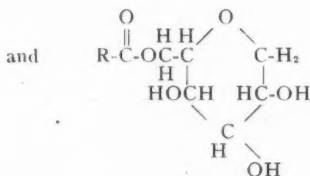
are representative.

The necessary adsorption may also be provided by two or more weaker dipoles in the same molecule as represented by the following compounds:



α -Mercaptostearic acid⁶

α -(2-carboxy phenoxy)-stearic acid⁹



Sorbitan monooleate¹⁰

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However, a molecule having only one group with weak attractive forces, such as R-OH, R-COOH, R-NH₂,

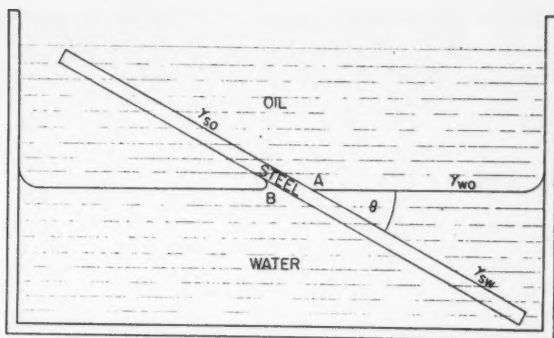
$$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}\equiv\text{N} \text{ and } \text{R}-\text{C}-\text{NH}_2 \end{array}$$
 is incapable of imparting significant protective action to the oil.

Displacement of Water by Oils

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Although rust-preventives are usually applied to dry surfaces, the protection of previously wetted steel parts, such as those from grinding, milling, and quenching operations, must be considered on occasion. While protection here can be accomplished first by drying and then

applying the preservative, it can also be provided in one operation by use of water-displacing preservative oils. Although straight mineral oil will not displace water, this desirable action can be made to occur by adding



$$DWO = \gamma_{so} - \gamma_{sw} = \gamma_{wo} \cos \theta$$

The receding angle, θ , is the stable angle obtained by rotating the steel strip to give a continuous horizontal interface at A. Interface at B would not be a continuous horizontal line unless θ is 90°.

Figure 4—Interfacial contact angle between oil, water and steel.

TABLE I.
Properties of Films on Polished Steel Surfaces

Additive	MANNER OF APPLICATION		Transferred from Water Surface and Dipped in Oil		Deposited from Volatile Solvent
	Transferred from Water Surface		No. of Monomolecular Layers and Type*	Humidity Cabinet† Life (Hrs.)	Humidity Cabinet Life (Hrs.)
None					
A	2V	<24	2V	<24	24
A	18V + 22X	<24	32V + 14X	430	24
B	2V	<24	2V	<24	..
B	32V	<24	32V	264	24
C	2V	<24	2V	<24	..
C	24V + 19X	<24	* 42V + 2X	196	..
D	6V	<24	6V	216	24
E	6V	88	6V	216	24

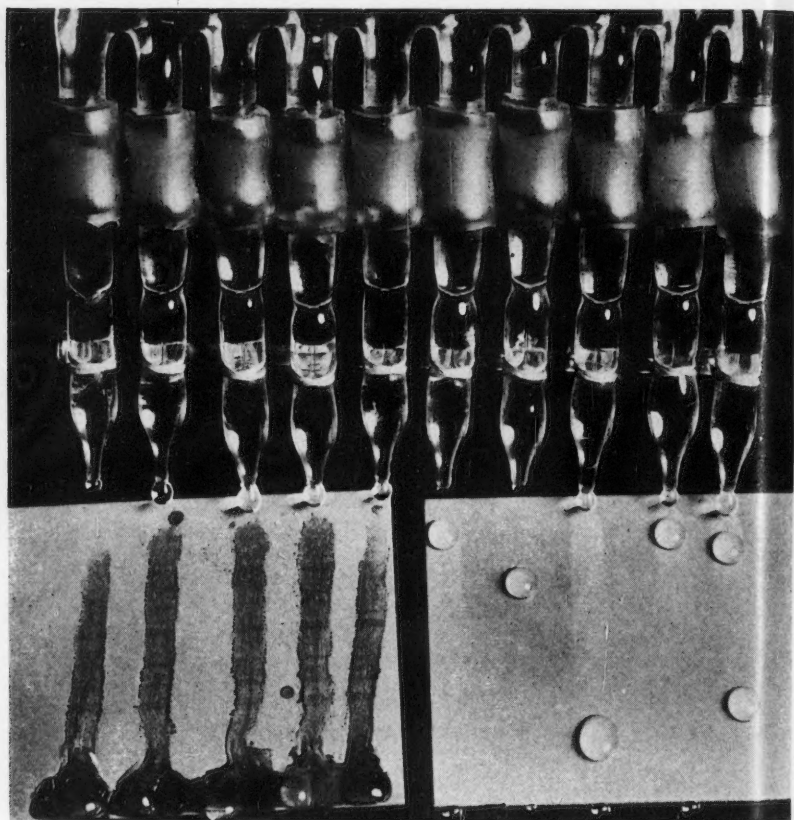
*V films consist of "alternating" layers of polar compounds



X films consist of "nonalternating" layers of polar compounds



† Humidity cabinet of the type and operated under conditions described in U. S. Army Specification 2-120 March, 1944. The number of hours represents the time for 10 percent or more of panel surface to rust.



The sand-blasted steel panel on left is covered with SAE 30 mineral oil, that on the right bears the same oil film containing an additive; both subjected to falling drops of dilute (0.05%) sodium chloride solution for 15 minutes.

Figure 5—Effect of polar compounds on rust-proofing efficacy of mineral oil.

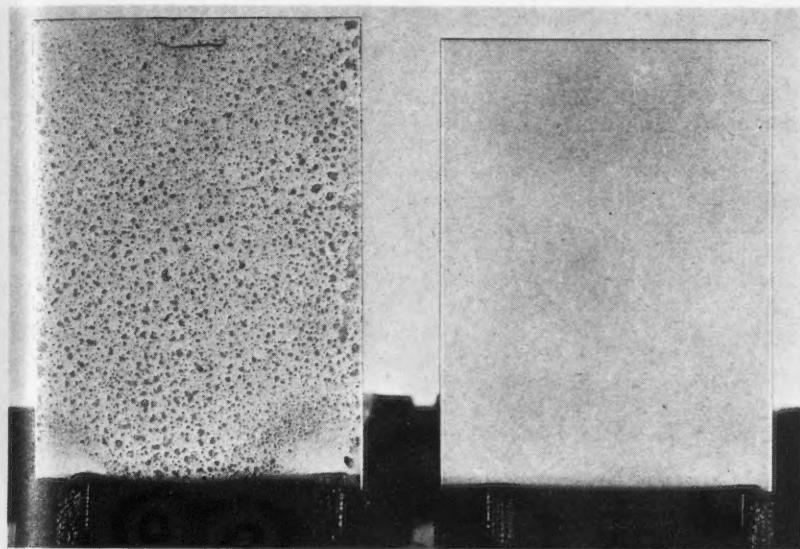
to the oil certain polar compounds which have a greater tendency than water to be adsorbed on steel. However, water displacing oils are not necessarily preservative oils, nor is the converse true, as discussed later.

The tendency of an oil to displace water from steel can be estimated by considering the relative surface energies at all the interfaces involved (Figure 4). A water-steel interface will be replaced by an oil-

steel interface if the energy of the system decreases as a result of this action. The difference in surface energy (D_{wo}) between a steel-oil and a steel-water interface (interfacial tensions γ_{so} and γ_{sw} respectively) can be calculated from measured values of the contact angle (θ) and the water-oil interfacial tension (γ_{wo}) according to the equation

$$D_{wo} = \gamma_{so} - \gamma_{sw} = \gamma_{wo} \cos \theta.$$

It follows that displacement of



Sand-blasted steel panel on left is covered with a film of SAE 30 mineral oil, that on right bears the same oil containing an additive; both subjected to the humidity cabinet at 100° F. and 100% relative humidity for 24 hours.

Figure 6—Effect of polar compounds on rust-proofing efficacy of mineral oil.

water by oil should be expected when θ is between 90 and 180°; on the other hand, displacement of oil by water would be expected when θ is between 0 and 90°.

Since the above equation represents an equilibrium of forces, the contact angle should be an equilibrium value, i.e., one that does not change with time and is independent of the manner in which it is formed. However, equilibrium values of contact

angles are seldom obtained experimentally,¹¹ the water-advancing angle usually being larger than the water-receding angle. Since measurement of the water-receding angle involves the movement of an oil interface over an area previously occupied by water, it might be expected that displacement energies calculated from such measurements would be a better indication of the water-displacing tendency of oils.

TABLE II.
Comparison of Displacement Energy (D_{wo}) and Water-Displacing Action

Oil.	Oil-Water Interfacial Tension (dynes/cm.)	Interfacial Contact Angle (°)	D_{wo} ergs/cm. ²	Observed Water* Displacing Action
Mineral Oil.....	49.7	5°	49.6	None
Mineral Oil + Additive A.....	23.6	5°	23.5	None
Mineral Oil + Additive B.....	8.9	5°	8.8	None
Mineral Oil + Additive C.....	8.9	140°	—6.3	Good
Mineral Oil + Additive D.....	4.6	150°	—4.0	Good
Mineral Oil + Additive E.....	20.3	115°	—8.6	Good

* See Figure 7 for description of water-displacing test.

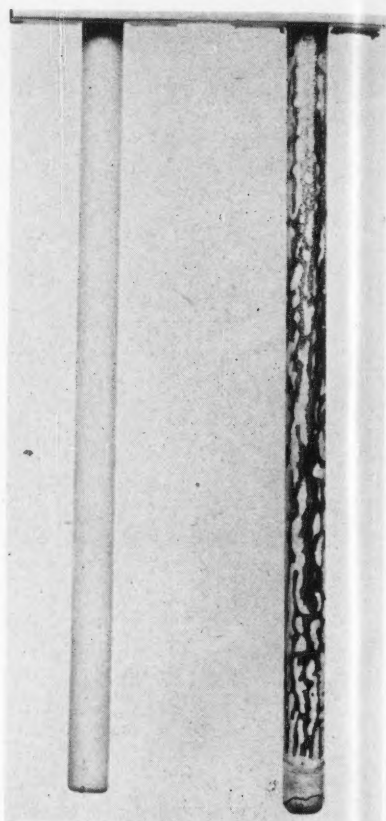
Comparison of displacement energies, calculated from water-receding angles and oil-water interfacial tensions,* with results of water-displacement tests shows good correlation between the sign of the displacement energy and water-displacing action (Table II). All the oils of negative displacement energy are effective in displacing water from steel, while those with a positive displacement energy are poor in this respect.

The fact that some additives act as water-displacing as well as rust-preventive agents, while others exhibit only one of these effects, probably is a function of the relative distribution of the additive at the various interfaces. While combination of adsorption at both the oil-water and steel-oil interfaces would remove water from steel, subsequent rust protection depends upon the magnitude of adsorption and chemical structure of the compound at the steel-oil interface as well as the thickness of the oil film. Hence, water displacing additives are not always good rust-preventive additives. Conversely, some additives may be sufficiently adsorbed on dry steel to improve rust protection but may not lower the oil-water interfacial tension enough to displace water from previously wetted steel surfaces.

Other Factors

While the results of these experiments provide a basic explanation of the action of rust-preventive oils, there are other factors which may be

* In these experiments interfacial contact angles were measured by a modification of the method of Wenzel¹² and the oil-water interfacial tensions with a du Noüy interfacial tensiometer.



In this test, sand-blasted steel rods were dipped momentarily in 0.05% sodium chloride solution, then immersed in the designated oil and the water-displacing action observed. After one minute, they were removed and allowed to hang in the laboratory 24 hours. The rod on right was immersed in an SAE 30 mineral oil, that on the left was immersed in the same oil containing a polar additive; both photographed after 24 hours.

Figure 7—Effect of polar compounds on the water-displacing action of mineral oil.

expected to influence the behavior of such oils. Piltz and Farley¹ have shown that low solubility of the additives in water favors rust-preventive efficacy. They also indicated that increasing temperature and decreasing molar concentration of the

additive would decrease protective action.

Furthermore, qualitative observations have indicated that the thickness of the oil film, the manner in which it is applied, formation of micelles, composition of metal surface, surface finish, and nature of the exposure environment all may affect the protection afforded by the oils. While adsorption plays an important role in rust protection, it is also possible that some additives (especially acids) react with the iron or its corrosion products to form salts which are insoluble in both oil and water and hence remain on the steel surface as a protective barrier.

These and probably other factors influence the protective characteristics of compounded mineral oils. Considerably more research would be necessary to evaluate properly the importance of each.

Summary

The following mechanism by which oil solutions of polar compounds protect steel is proposed:

Polar molecules are adsorbed as oriented multimolecular layers at the steel-oil interface.

These layers retain oil in their interstices, forming a mixed film which is more impervious to water than either the additive or oil alone.

Additives with weak attractive forces forming only mono- or bimolecular layers are not effective rust inhibitors. A minimum of about six molecular layers is required to form an effective barrier against moisture.

Compounded oils displace water from steel if the adsorptive forces of the additive for steel are greater than those of water for steel and consequently form a more stable interface (one of lower energy).

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Prevention of Corrosion in Lead Sheathed Cables By Means of a Vulcanized Protective Covering*

By B. B. Reinitz* and N. A. Zamborsky*

L EAD SHEATH corrosion has long been recognized as a major factor in the service failure of lead covered cables. Present improved methods of producing extruded lead sheaths have largely eliminated inherent defects which were the outstanding causes of cable failures in the past. This has placed added emphasis on failures of a non-inherent nature. The latest available data of the Associated Edison Illuminating Companies on power cable operation shows that 28 percent of non-inherent failures are caused by corrosion of lead sheath.

The purpose of this article is to show that complete electrical and mechanical protection against corrosion for the entire length of cable can be provided by the use of a vulcanized protective covering applied at the factory, at relatively low cost.

Types of Corrosion

Corrosion can result from (a) the reaction between the metal and the corrosive media involving differential aeration where the metal is at

different potentials in relation to oxygen availability, (b) galvanic action where dissimilar metals are involved, (c) stress differential as in the scoring of lead in process of installation, and (d) stray as well as other electric currents in the presence of an electrolyte.

Chemical Corrosion Caused By Differential Aeration

Chemical corrosion caused by differential aeration is a common type of corrosion and readily demonstrated by a simple laboratory experiment. Sections of cable sheaths were partially submerged in various solutions in mason jars in an inclined position and sealed. They were under test for 15 months. Examination after removal disclosed corrosion products largely on the unsubmerged part. The corrosion products as determined qualitatively together with corroded samples are shown in Figure 1. An interesting point is that calcium hydroxide seems to cause the severest corrosion as apart from the usual corrosion products formed; red lead (Pb_3O_4) was also detected. This is in line with the findings of other investigators.^{1,2}

* A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

* The Okonite Callender Cable Co., Inc., Paterson, N. J.

CORROSION PRODUCTS		IMMERSION SOLUTION
Lead oxide, PbO Red lead, Pb_2O_3 Lead carbonate, $PbCO_3$	No. 9 LEAD OXIDE	1% Lime water
Lead oxide, PbO	No. 8 N/10 AMMONIUM HYDROXIDE	N/10 Ammonium hydroxide
Hydrated lead monoxide, $2PbO \cdot Pb(OH)_2$ Lead carbonate, $PbCO_3$ Lead oxide, PbO	No. 7 N/10 CALCIUM SULFATE	N/10 Calcium sulfate
Hydrated lead monoxide, $2PbO \cdot Pb(OH)_2$ Lead carbonate, $PbCO_3$ Lead chloride, $PbCl_2$ Lead oxide, PbO	No. 6 N/10 SODIUM CHLORIDE	N/10 Sodium chloride
Lead carbonate, $PbCO_3$ Lead hydrate, $Pb(OH)_2$	No. 5 N/10 SODIUM CARBONATE	N/10 Sodium carbonate
White lead, $2PbCO_3 \cdot Pb(OH)_2$ Lead oxide, PbO	No. 4 TAP WATER & CO_2 & 1% ACETIC ACID	Tap water + CO_2 + 1% acetic acid
Hydrated lead monoxide, $2PbO \cdot Pb(OH)_2$ Lead carbonate, $PbCO_3$	No. 3 TAP WATER & CO_2	Tap water + CO_2
Hydrated lead monoxide, $2PbO \cdot Pb(OH)_2$ Lead carbonate, $PbCO_3$	No. 2 MANHOLE WATER & CO_2	Manhole water + CO_2
Hydrated lead monoxide, $2PbO \cdot Pb(OH)_2$ Lead oxide, PbO	No. 1 MANHOLE WATER	Manhole water

Figure 1—Corrosion of cable sheaths after immersion in various solutions for 15 months.



Figure 2—Typical example of scoring of lead caused by pulling through duct.

Galvanic Corrosion

A good example of galvanic corrosion occurred in the case of telephone cables laid in cement ducts. Here the presence of calcium hydroxide, $\text{Ca}(\text{OH})_2$, was the major cause of corrosion, yet failure was hastened by galvanic action resulting from the unequal distribution of 3 percent tin in the lead alloy and by the inner iron sheathing.³ Galvanic corrosion is accelerated even to a greater extent in the case of lead-antimony alloys where the electrochemical corrosion is the result of the existence of a potential difference between the solid solution and dispersed antimony particles.

Stress Differential

It is well known that a stressed part of a metal becomes anodic and is therefore more readily corroded than the unstressed part. This has been quite noticeable when cables have been pulled through a rough duct line. The bottom portion of the sheath disclosing pronounced scoring (Figure 2) will also show signs of corrosion.

Stray and Other Electric Currents

Most frequent causes of corrosion are stray current electrolysis from street railways or other sources of d-c flow in the earth. Corrosion takes place where electric currents dis-

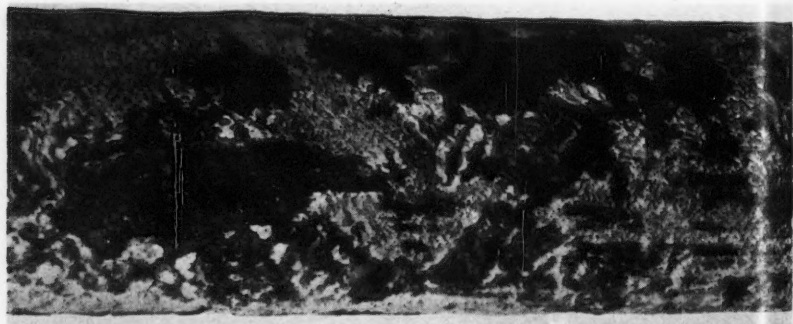


Figure 3—Lead-sheathed cable damaged by corrosion—the largest single cause of trouble with lead sheaths.

charge from a metal surface to the surrounding soil, but no corrosion occurs⁴ where this current collects in its return to complete the circuit. Initially intercrystalline corrosion takes place, then it is followed by the disintegration of grains. Generally there is pronounced pitting in a straight line (Figure 3). Apart from the separation of crystal grains at the boundaries, corrosion products, such as lead peroxide (PbO_2) and red lead (Pb_3O_4) are usually detected.

Irrespective of the type of corrosion encountered, some form of electrolyte has to be present.⁵ Analysis of typical electrolytes found in duct lines and manholes located quite far apart from each other is shown in Table I. Some of the results reported have been calculated as compounds and are believed to be present in such combinations. When cable sheaths were partially submerged in these waters in sealed jars, corrosion was most pronounced where the alkalinity was the highest (pH-11.9). At the same time, chlorides, sulfates and bicarbonates, where the alkalinity is lower (pH-8.5) also cause appreciable corrosion, as confirmed by Loschiavo.⁶

Preventive Measures

Various methods are in use to prevent damage to lead sheathed cables from corrosion. Some of these protective methods are: cathodic protection, use of protective greases, asphalt or bituminous saturated fibrous tape or jute coverings, various other protective coverings, grading duct lines, neutralizing agents for flushing duct lines, substitution of non-metallic sheathed cables, use of

TABLE NO. I
Composition of Typical Manhole Waters

	Parts per Million	
	Sample 1	Sample 2
Total solids (105° C.).....	660	2970
Loss on ignition.....	75	200
Silica, SiO_2	20	30
Iron aluminum oxide, FeAlO_3	20	70
Calcium bicarbonate, $\text{Ca}(\text{HCO}_3)_2$	414	1270
Magnesium bicarbonate, $\text{Mg}(\text{HCO}_3)_2$	80	393
Calcium sulfate, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	390	.....
Sodium sulfate, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$.....	.....	1070
Sodium chloride, NaCl	12	1052
Sodium hydroxide, NaOH}.....	.....	611
Lead chloride, PbCl_2.....	.....	284
pH.....	8.5	11.9

Examination of Lead Pipe After Immersion in Above Manhole Waters

	Sample 1	Sample 2
Corrosion.....	Appreciable	Pronounced
Corrosion products	Hydrated lead monoxide, $2\text{PbO} \cdot \text{Pb}(\text{OH})_2$; lead carbonate, PbCO_3	Hydrated lead monoxide, $2\text{PbO} \cdot \text{Pb}(\text{OH})_2$; lead carbonate, PbCO_3 ; lead oxide, PbO

current drainage bonds and insulating joints.

Of various methods that have been proposed and put into effect, however, most of them have their limitations as the conditions imposed are extremely severe. If duct lines could be kept entirely free of moisture and chemicals, the problem would be simple. Since it is not economically feasible to maintain such conditions the usual procedure is to either resort to cathodic protection or current drainage by means of insulating sleeves and joints or one of these procedures in conjunction with some protective coating or covering.

Great care has to be exercised where cathodic protection is employed as the alkali that may be produced may bring about severe cor-

rosion to the lead sheath.^{7,8} Moreover, the cathodic method has limited application in congested areas as special precautions must be taken in order to prevent current discharging to other metallic installations which are not included in the protective plan.⁹

According to Phelps,¹⁰ insulating sleeves may increase or decrease corrosion. Even where insulating joints are used to break up the continuity of the sheath, it was found that under severely corrosive conditions protective coverings also had to be used.¹¹ Moreover, sleeves are complicated and considered of doubtful value in very moist soils as it is difficult to prevent local currents from entering and leaving the sheath.⁴

Essential Features for Corrosion-Resistant Coverings

Numerous protective coatings and coverings used in the past were deficient in some respects and thus their usefulness was limited. Of 24 coatings investigated¹² none was found satisfactory. This is understandable when it is considered that for a coating to be dependable it must be immune to various electrolytes, oil, greases, temperature fluctuations, stray currents and ground potentials. Furthermore, it must be able to withstand the stresses imposed in process of handling and installation; its thermal conductivity should be good; above all, it should expand and contract with the metal under operating conditions. Finally, it should not stick to the duct wall and should possess a low coefficient of friction.

Most protective coverings have not been given a favorable recep-

tion as in many instances they consisted of asphalt with saturated canvas or duck tape. Difficulty was experienced in pulling cable into or out of ducts due to increased diameter and tendency of asphalt to stick to duct walls. In fact, there is an instance on record where a cable length and duct run were abandoned because the deteriorated fabric clogged the duct thus preventing removal of the cable.⁹ A covering was desired that would insulate the metal sheath against electrolytic action and mechanically protect the sheath from chemical corrosion. The thickness of the protective covering was restricted in order not to materially increase the overall diameter of cables to be installed in existing duct lines. The covering must be economical.

Vulcanized Neoprene Covering

Years ago we were aware of the seriousness of corrosion in underground cable sheaths. We investigated all types of materials; those showing the most promise, Table II, were investigated further and tested. These included both thermoplastic and thermosetting materials. They were applied in tape form as well as extruded in the form of jackets. These tests and investigations together with the favorable results reported under service conditions^{9,11} provided a clear indication of the superiority of a compound made from neoprene which could be applied over the cable and securely bonded to the lead sheath. In addition to its satisfactory electrical and superior mechanical properties when vulcanized, this compound also is highly resistant to moisture, oils, chemicals, and is nonflammable.

TABLE NO. II

Immersion Test Results of Various Protective Coverings

Cable sections protected with coverings described below continuously immersed in a 3% salt solution and exposed to atmosphere with a potential of 10 volts dc between the lead sheath and salt solution.

TYPE OF COVERING	Thickness of Covering, Mils	Time of Immersion, Months	Condition
1. Okosheath protective covering.....	115	72	No corrosion; covering in excellent condition.
2. Two layers rubber tape, two layers rubber filled fabric tape, corrosion resistant paint.	125	71	No corrosion; friction tape deteriorated, rubber in good condition.
3. Two layers oil-base rubber compound tape, remainder as in 2.	125	66	No corrosion; friction tape deteriorated, rubber compound in good condition.
4. Extruded synthetic plastic (ethyl cellulose)	105	53	No corrosion; poor abrasion resistance, cold flow of covering.
5. Extruded synthetic plastic (polyvinyl chloride)	110	53	No corrosion; cold flow of covering.
6. Extruded synthetic plastic (co-polymer, polyvinyl chloride and polyvinyl acetate)	90	53	No corrosion; cold flow of covering.

It can be applied with regular factory equipment at a relatively low cost.

Description of Covering

Over the bare lead sheath a layer of fabric tape filled with neoprene compound is applied, followed by a layer of neoprene, 70 mils thick; over this is a double thickness of heavy fabric tape filled with neo-

prene and treated with fungicide. The covering is then vulcanized to fuse the component parts into a solid mass and give the neoprene compound high mechanical strength. The vulcanized neoprene will meet ASTM requirements for heavy duty service particularly with regard to a tensile strength of 1800 pounds per square inch. Vulcanization also

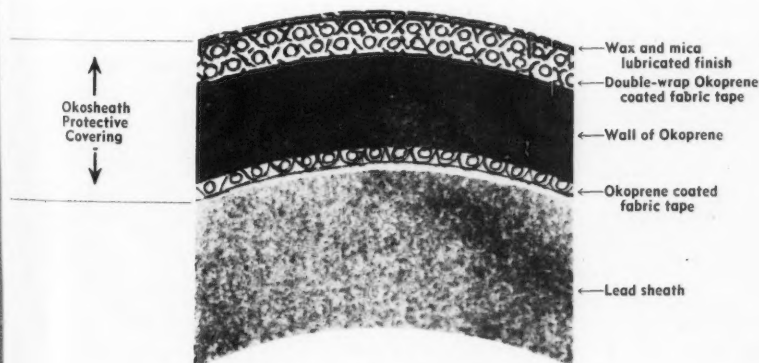


Figure 4—Cross-sectional view of protective covering.

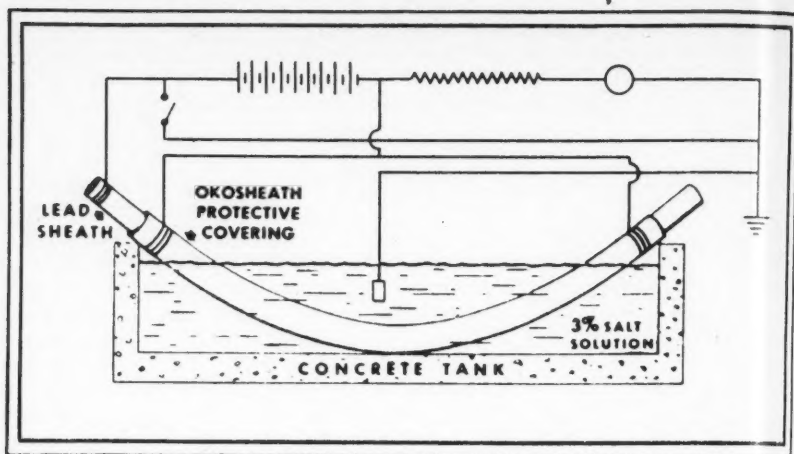


Figure 5—Simplified diagram of 6-year tank test.

bonds the inner fabric tape firmly to the lead sheath.

After vulcanization, the covering is flushed with a finishing compound and dusted with a mixture of talc and mica dust. The total thickness of the complete covering is 115 mils, containing a 70 mil wall of neoprene free from any fabric which might act as a wick for moisture and corrosive chemicals to pass through the covering and attack the lead sheath (Figure 4). Extensive laboratory tests have been conducted for extended periods on lead sheathed power cables protected with the covering all with highly favorable results.

Laboratory and Field Performance Tests

One of these tests was the immersion of cable protected with the covering in a concrete tank containing a 3 percent salt solution (Figure 5). The metallic sheath is attached to the positive pole of a 10-volt

battery. The voltage is on continuously between the sheath and the salt solution making the metallic sheath positive. The current leakage through the jacket is measured with a milliammeter connected in series with a 10,000-ohm resistance. From this, the resistance in ohms is calculated. Periodic measurements are made and when the resistance falls below 50,000 ohms, the test is discontinued and the sample examined to determine the cause of failure. After six years in the tank, the insulation resistance was in excess of 250,000 ohms. Upon removal and examination, the protective covering showed no sign of deterioration and the lead sheath was entirely free of any corrosion damage.

Other specimens of cable with the protective covering have been buried for many years in our outdoor proving ground, where the most severe corrosive environments found in service have been duplicated. These

TABLE NO. III

Internal Pressure Test on Composite Sheath Compared to Plain Copper-Silver-Bearing Lead
 CABLE DESCRIPTION: Single conductor; 500,000 CM concentric strand; 203 mil wall of impregnated paper insulation.

Internal Pressure Lbs. Sq. In.	COMPOSITE SHEATH		STANDARD PLAIN SHEATH	
	60 Mil Okometal (Lead Alloy) Plus Okosheath Protective Covering		95 Mil Wall Copper-Silver-Bearing Lead	
	Hours on Pressure	Total Hours	Hours on Pressure	Total Hours
90.....	336	336	336	336
100.....	168	504	168	504
110.....	168	672	168	672
120.....	168	840	168	840
130.....	168	1008	168	1008
140.....	168	1176	168	1176
150.....	912*	Over 2088	312 pipe burst	1488

* The composite sheath was still on test after having withstood 150 lbs./sq. in. for 912 hours without failure.

cables have shown no sign of deterioration of the covering or corrosion of the lead sheath when removed from the proving ground.

As a field test, a 150-foot length of cable with protective covering was placed in a utility standard duct line which was known from past experience to contain conditions highly corrosive to lead. The cable was installed in 1933. It has been removed, carefully inspected and reinstalled periodically. After 13 years, the pro-

tective covering was reported in good condition although the outer fabric tapes showed some deterioration because of repeated pulling in and out of the duct for examination.

A southern utility has recently reported the good protection offered by this covering. A length of bare lead sheathed cable recently failed after seven years of service because of corrosion of the lead sheath. In the same duct bank a length of similar cable covered with the protec-

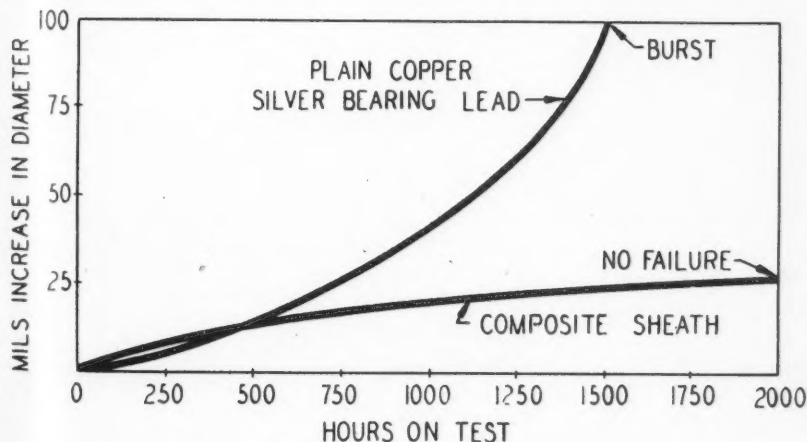


Figure 6—Diameter change during internal pressure test.

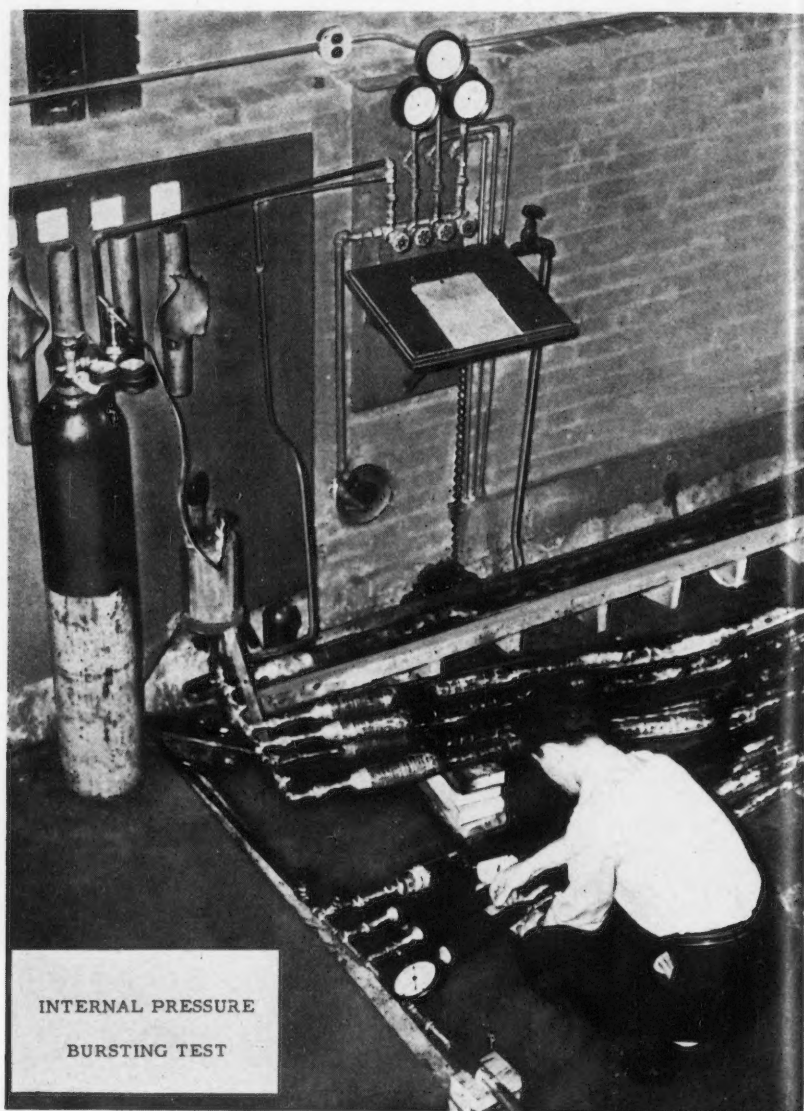


FIGURE 7

TABLE NO. IV

Manhole Bend Test on Composite Sheath Compared to Plain Copper-Silver-Bearing Lead

CABLE DESCRIPTION: Three conductor; 500,000 CM compack sector; 150 mil wall of impregnated paper insulation; shielded type.

TYPE OF SHEATH		Cycles to Failure	Equivalent Life Years
Standard Plain Sheath...	120 mil wall Copper-silver-bearing lead.....	6000	22.2
Composite Sheath.....	80 mil wall Okometal (lead alloy) plus 0.115" of Oko-sheath Protective Covering	14,440	53.5

tive covering and installed three years earlier is still in service with no indication of corrosion of the lead sheath.

The covering has been supplied on single and multiple conductor cables in sizes No. 2 AWG to 3,000,000 CM and for all voltages through 138,000 volts. It has been used on low-pressure gas filled and oil-filled as well as solid type cables and has also been applied under the armor on submarine cables. In some instances, utilities have removed cables from service in locations found to be corrosive to lead, and shipped them to the factory for application of the protective covering.

Additional Advantages

The protective covering acts as reinforcing when applied over lead or lead alloy cable sheathing. It has been found possible to reduce the thickness of the lead or lead alloy sheath normally applied to cable when used in combination with the protective covering. Table III shows a comparison of internal pressure tests conducted on cable with normal thickness of unprotected sheath and the composite sheath consisting of reduced thickness alloy lead plus the protective covering.

The test consists of subjecting

30-foot lengths of cable to internal pressure maintained at constant values in increasing steps for specified periods of time. During these tests the increase in outside diameter of the sheath in each case was measured. The comparative results appear in Figure 6. The set-up used in the laboratory for making the internal pressure test is shown in Figure 7.

Laboratory tests have demonstrated that the resistance of lead or lead alloy sheaths to failure attributable to cyclic bending in manholes has been materially increased through the use of the protective covering. Table IV shows the results of dummy manhole bending tests conducted on cable with normal thickness of unprotected lead, and the composite sheath of reduced lead alloy thickness plus the protective covering. In this dummy manhole, actual lengths of cable with joints included, are trained with standard contours and subjected to $\frac{1}{2}$ -inch movement at each end in 4-minute cycles. Sufficient current is applied to obtain sheath temperatures equal to average field conditions. In this, and similar test set-ups used by several large utilities, 270 cycles of bending are considered equivalent to one year of actual service. The labora-

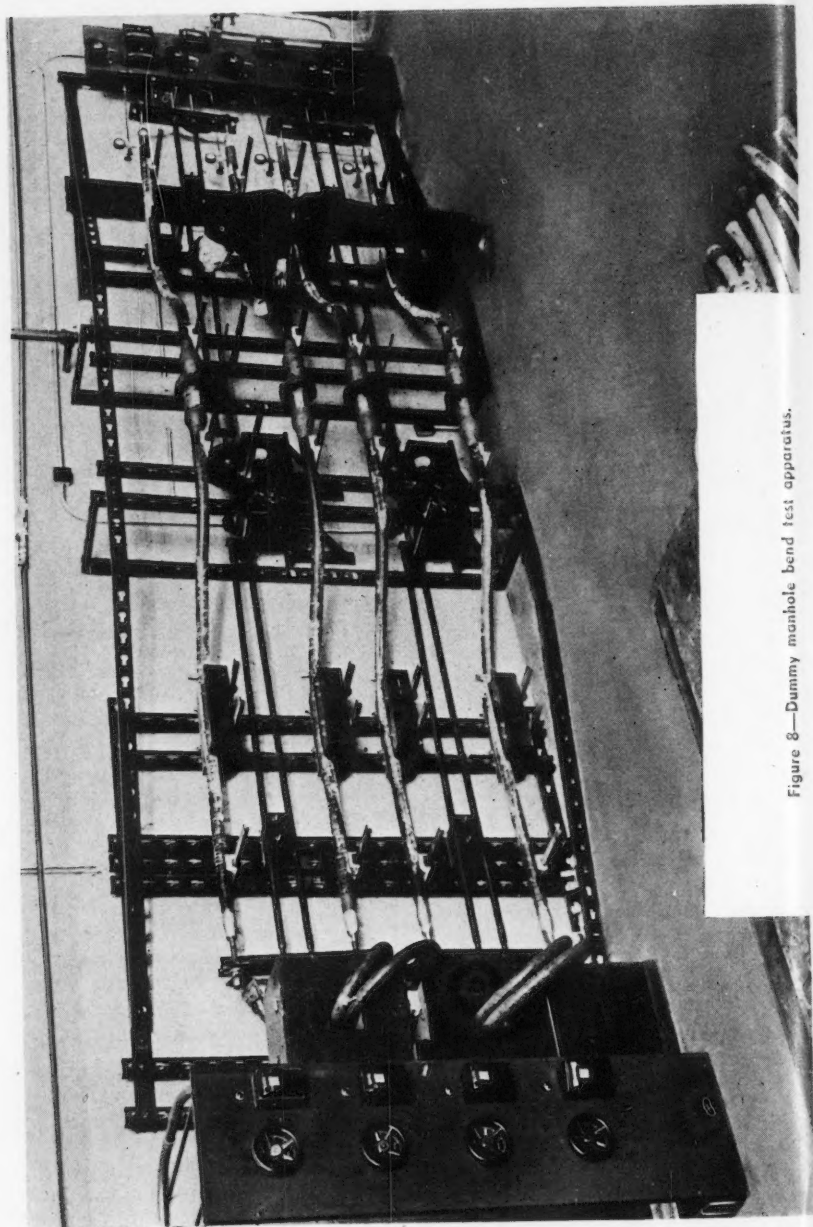


Figure 8—Dummy manhole bend test apparatus.

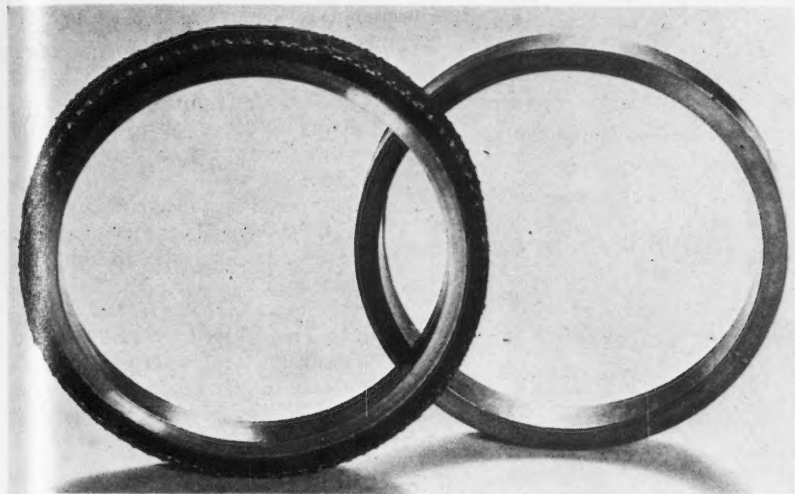


Figure 9—Reduced lead wall plus protective covering versus standard lead wall (same core dimensions).

tory dummy manhole bend test apparatus is illustrated in Figure 8.

The reduction in thickness of the lead or lead alloy sheath when used in combination with the protective covering has made it possible to reduce the cost of the protective covering so that this distinctly superior composite sheath (Figure 9) can be manufactured to sell at only a slightly higher price than cable covered with a bare lead sheath of normal thickness.

It has been reported by utilities that the pulling tension required to install cables in duct lines has been reduced approximately 25 percent when the protective covering is used. This results in economies for the user through the use of longer duct runs with fewer manholes and reduced construction costs. A further saving can be realized by eliminating the costly practice of construct-

ing graded or "down hill" duct lines where the protective covering is used.

Prevention of all mechanical damage such as, scoring of the lead or lead alloy sheath of cable during installation is accomplished by the protective covering. Fifteen percent of the specified lead sheath thickness is the factor of safety allowed for scoring damage.

Fifteen years of trouble-free service in the field have confirmed long and careful laboratory tests proving that a protective covering of vulcanized neoprene provides the most satisfactory method of protecting underground lead or lead alloy sheathed cables from all types of corrosion. Moreover, it allows a substantial reduction in the thickness of the metallic sheath and provides at low cost many additional advantages.

Summary

1. The vulcanized protective covering prevents chemical, galvanic and electrolytic corrosion.

2. Increases resistance to manhole bending fatigue.

3. Reinforces the lead or lead alloy sheath; thus reducing expansion resulting from internal pressure.

4. Permits a substantial reduction in thickness of lead or lead alloy sheath.

5. Protects the metallic sheath

against mechanical damage during installation.

6. Reduces pulling tensions, permitting the use of longer cable lengths with fewer manholes and joints.

7. Economies in installation and maintenance costs are brought about by the elimination of grading and flushing of duct lines.

8. Current interest in reduced thickness of lead or lead alloy increases the emphasis on the effectiveness of the protective covering.

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Discussion

Hezzie Clark:* "Mr. Reinitz, you state that Okoprene as used in providing the Okosheath covering for lead covered cables is highly impervious to moisture. It is my thought that some of us may feel that there is no need for lead sheathing, so I ask, why use lead sheathing?"

Mr. Reinitz: "The word 'impervious' is strictly relative and although it is highly impervious to moisture it is not moisture proof. Therefore, it cannot be considered as a replacement for lead sheathing and is used for protection to the lead sheathing against corrosion."

* Humble Pipe Line Co., Houston, Texas.

Application of Electron Diffraction Techniques To the Study of Corrosion Processes*

By E. A. Gulbransen*

Introduction

ONE OF THE MOST interesting and instructive uses of the electron diffraction and electron microscope methods has been the study of the nature of the protective or non-protective corrosion films on metals and alloys. The use of such refined methods is due to the fact that in the protective range the corrosion films are of the order of 10 to 10,000 angstroms in thickness. The study of the crystal structure, crystal size and secondary structure of films in this thickness range can be made only by the use of the electron diffraction method and by electron microscopy. Thicker films can be studied by the use of X-ray diffraction methods and the light microscope.

The reaction involved in the dry oxidation of metals and alloys from a chemical point of view is simpler than many other corrosion reactions. However, from an experimental point of view it may be more difficult. This is due to the fact that the oxidation reaction is best studied in the electron camera itself at high temperatures. The application of the electron diffraction method to wet corrosion processes is not

difficult if the reaction is uniform and pitting does not occur. The study of the material present on the surface in small pits is a difficult problem and not one readily solved by electron diffraction methods. This article pertains primarily to the dry oxidation reaction. The experimental work given in this paper has been previously reported.^{1,2} Before discussing the apparatus, method and results it is of interest to see what relationships the information given by the electron diffraction method bears to the general problem.

Study of Surface Reactions

Table I shows the relationship of the electron diffraction and electron microscope techniques to the general study of the dry oxidation surface reaction. The general problem may be broken down into three groups of studies. The first group of studies is concerned with the kinetics or the rate of reaction and in what manner this rate is influenced by time, temperature, pressure, surface factors and chemical factors in the gas atmosphere. We have used a vacuum microbalance technique for a considerable number of these studies.^{3,4}

The second class of studies is concerned with the structure factors. These structure factors include the crystal structure, primary structure

* A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

* Research Chemist, Westinghouse Research Laboratories, East Pittsburgh, Pa.

TABLE I.
Study of Surface Reactions

A. Rate of Reaction 1. Time 2. Temperature 3. Pressure 4. Surface Factors 5. Chemical Factors	Vacuum Microbalance Technique
B. Structure Factors 1. Crystal Structure 2. Primary Structure 3. Secondary Structure	Electron Diffraction, X-Ray Diffraction Electron Diffraction, X-Ray Diffraction, Electron Microscope Electron Microscope, Light Microscope
C. Other Factors 1. Atomic Composition of Film 2. Lattice Defects and Impurities in Film 3. Mechanism of the Diffusion or Reaction Process	Chemical Analyses, Electron Analyzer? Hall Effect?, Conductivity Measurements? Electron Diffraction, Radioactive Tracers?

and secondary structure. The crystal structure refers to the atomic geometry of the atoms, molecules or ions that make up the unit cell and the dimensions of the cell and the several angles involved. This unit cell is the fundamental structural unit in matter. The metals and their oxides usually follow the simpler types of structural arrangements. The oxides FeO (ferrous oxide), NiO (nickelous oxide) and CoO (cobaltous oxide), for example, all follow the face-centered cubic structure and are different only in their cell dimensions. Table II lists some of the metals and their oxides which have been studied together with their structures and unit cell dimensions.

The primary structure is concerned with the size and shape of the crystals which make up the particles in the film. Each crystal contains many of the fundamental unit cells.

The secondary structure refers to the particle size and shape and how these particles are fitted together in the film. The particle may contain one or many of the crystals.

In the thin film range, the crystal

structure is obtained from an analysis of the electron diffraction pattern ring diameters and line intensities and a comparison with X-ray data.

The primary structure or crystal size and shape may be estimated from the width of the diffraction lines and the spot structure of the diffraction ring. However, certain precautions must be observed in using such an analysis on electron diffraction patterns.

The secondary structure can be observed only with the electron microscope study of the films stripped from the metals. For thick films this structure may be observed with the light microscope.

The third class of factors include (1) the atomic composition or chemical composition or chemical analyses of the film, (2) the lattice defects and impurities in the film, (3) the mechanism of the reaction. These may be studied by a variety of techniques (shown in Table I) and will not be discussed further.

In general, no one technique, method or physical tool can solve a complicated corrosion problem. The information obtained with the electron diffraction method is of great

TABLE II.
Lattice Parameters of Metals and Metallic Oxides

Substance	a	b	c	α	Structural Type
Fe.....	2.86	.....	.....	.....	Body-centered cubic
W.....	3.16	.....	.....	.....	Body-centered cubic
Cr.....	2.88	.....	.....	.....	Body-centered cubic
V.....	3.03	.....	.....	.....	Body-centered cubic
Ni.....	3.52	.....	.....	.....	Face-centered cubic
Co.....	2.51	.....	4.07	.....	Hexagonal close-packed
Mn.....	8.89	.....	.....	.....	Cubic
Si.....	5.42	.....	.....	.....	Cubic (diamond)
FeO.....	4.28	.....	.....	.....	Face-centered cubic
CoO.....	4.25	.....	.....	.....	Face-centered cubic
NiO.....	4.17	.....	.....	.....	Face-centered cubic
WO ₃	4.86	.....	2.77	.....	Tetragonal
Cr ₂ O ₃	5.35	.....	.....	54° 58'	Rhombohedral
γ -Fe ₂ O ₃	5.42	.....	.....	55° 17'	Rhombohedral
W ₂ O ₅.....	.....	.....	.....	.....	Rhombohedral
WO ₃	7.28	7.48	3.82	.....	Monoclinic
V ₂ O ₅	5.43	.....	.....	53° 53'	Rhombohedral
V ₂ O ₃	11.48	4.36	3.55	.....	Orthorhombic
SiO ₂	4.90	.....	5.39	.....	Hexagonal
MnO.....	4.44	.....	.....	.....	Face-centered cubic
MnO ₂	4.44	.....	2.89	.....	Tetragonal
Mn ₂ O ₃	5.75	.....	9.42	.....	Tetragonal
Fe ₂ O ₃	8.40	.....	.....	.....	Spinel (cubic)
Co ₂ O ₃	8.11	.....	.....	.....	Spinel (cubic)
γ -Fe ₂ O ₃	8.32	.....	.....	.....	Cubic
MnO.Cr ₂ O ₃	8.42	.....	.....	.....	Spinel (cubic)
NiO.Cr ₂ O ₃	8.31	.....	.....	.....	Spinel (cubic)
CoO.Cr ₂ O ₃	8.32	.....	.....	.....	Spinel (cubic)
FeO.Cr ₂ O ₃	8.35	.....	.....	.....	Spinel (cubic)
MnO.Fe ₂ O ₃	8.51	.....	.....	.....	Spinel (cubic)
NiO.Fe ₂ O ₃	8.34	.....	.....	.....	Spinel (cubic)
CoO.Fe ₂ O ₃	8.39	.....	.....	.....	Spinel (cubic)

est value when properly correlated with other studies.

Transmission and Reflection

Methods of Electron Diffraction

Development of electron diffraction analysis as a tool for the study of surface chemistry arose from the prediction by De Broglie in 1924 that a wave system is associated with particles in motion. According to this prediction the wave length λ of the associated wave train is

given by the equation $\lambda = \frac{h}{mv}$.

Here v is the velocity of the electron, m the mass and h is Planck's constant. This prediction led to a series of experiments to prove that a homogeneous beam of electrons could be diffracted by a grating formed by the atoms of a crystal. The success of these experiments led

to the development of a method for identifying the atomic grating (determining the arrangement of atoms in a space lattice) by correlating the wave length of the electrons with the location and intensity of the diffracted beams.

An important milestone in this development was the discovery in 1930 that electrons impinging at near-grazing angles on plane surfaces would give diffraction rings characteristic of the surface material itself. This technique of electron diffraction is called the reflection method.

Thin specimens of matter (or small fragments or powders) can be studied directly by passing the beam of electrons through the material and observing the diffraction pattern on a fluorescent screen or photographic film. This earlier technique

is called the transmission method, and its results give a statistical view of the material, as though it were viewed—or penetrated—from all possible angles.

Since the scattering of electrons in matter is very high, the penetrating power of the electrons is extremely small. Therefore, the reflection method must be used to study opaque metal surfaces. In this method only the first few atomic layers are effective. A new method is now available for studying the boundary layer so important in the chemistry of metal surfaces.

The electron diffraction camera in use at the Westinghouse laboratories is shown schematically in Figure 1. The apparatus consists essentially of a source of homogeneous high voltage electrons of 30,000 to 60,000 volts energy, a magnetic focussing coil, a sample holder and manipulator, a camera section, and pumps for maintaining the vacuum. The camera includes a fluorescent screen by which the electron pattern can be made visible and a photographic film which permanently records it. To reduce the scattering of electrons the apparatus is continuously evacuated by a series of pumps to a very low pressure.

To obtain a good pattern by the

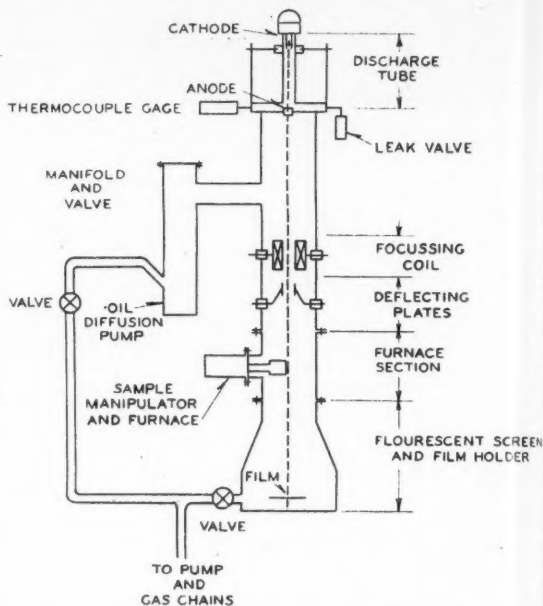


Figure 1—Schematic diagram of electron diffraction camera.

reflection technique the samples must be plain, crystalline and somewhat abraded. The surface preparation is important. Usually the specimens are abraded flat with various grades of polishing paper, using kerosene as a lubricant. Care must be taken to prevent external contamination of the surface.

If it is necessary to study the behavior of the specimens at high temperatures, they can be mounted in a furnace and studied in any gas atmosphere and at the temperature of interest. This scheme is useful for corrosion studies.

Figure 2 shows schematically the variables involved in the analysis of reflection patterns. The polycrystalline specimen at a distance L from the film diffracts electrons giving

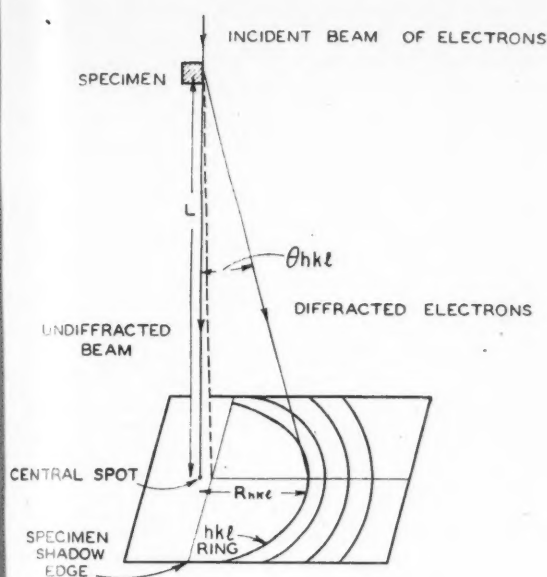


Figure 2—Reflection method.

Methods of Study and Results

a. Existence Diagrams

One of the most instructive ways of studying surface reactions using the electron diffraction method is studying the change of the crystal structure as a function of one or more variables. In the case of dry oxidation these variables might be time, temperature, pressure, surface preparation, pretreatment, etc. Such information may then be correlated with rate data, physical structure or performance characteristics of the

material. The radii of the diffraction rings and the relative intensities of the lines are used to identify the material while the breadth of the line and the presence of arcs and spots denote the crystal size and orientation. The data may be plotted on a temperature-time chart and the regions of stability of the several oxides can be seen from the chart. The presence of two different crystal structures in the chart indicates that transformations are occurring as a function of time and temperature.

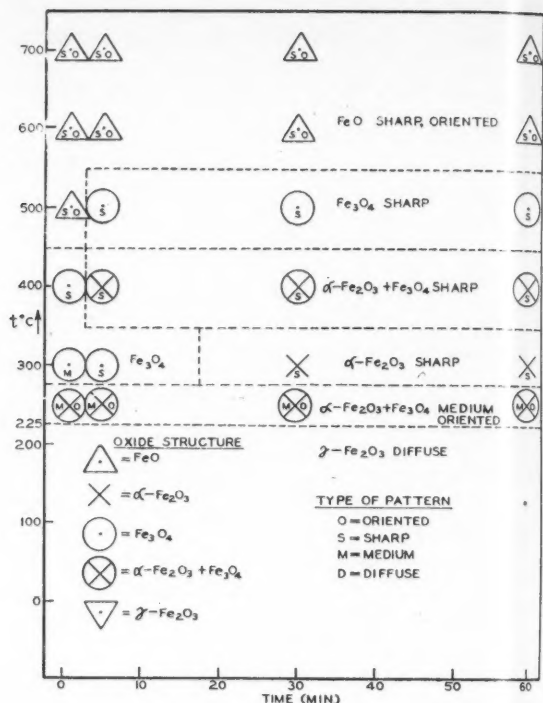
Figure 3 shows the existence diagram for pure iron. Four distinct oxide crystal structures are observed. These are $\gamma\text{-Fe}_2\text{O}_3$ (gamma ferric oxide), Fe_3O_4 (ferroferric oxide), $\alpha\text{-Fe}_2\text{O}_3$ (alpha ferric oxide) and FeO . $\gamma\text{-Fe}_2\text{O}_3$ and Fe_3O_4 obey the

ing rings of radii $R_{hk\ell}$. The undiffracted beam is shown striking the film behind the shadow edge. Bragg's law relating the diffraction angle to wave-length and lattice spacing can be applied to electron diffraction as well as to X-ray diffraction. For small angles Bragg's law simplifies to $R_{hk\ell} = \lambda L / d_{hk\ell}$. Here λ is the wave-length and $d_{hk\ell}$ is the lattice spacing effective in producing the diffraction $_{hk\ell}$.

The instrument can be calibrated by directly determining the voltage and thus λ or by measuring the diffraction pattern of known materials and calculating the values of λ .

The precision obtained in the calculation of the unit cell size for cubic structures from the $d_{hk\ell}$ values is of the order of 0.3 percent.

Figure 3—Oxide films on iron, 1 mm oxygen. Various times and temperatures.



cubic spinel structure, α -Fe₂O₃ the rhombohedral structure and FeO the face-centered cubic structure. The terms D, M, S and O refer to the characteristics of the diffraction pattern. D refers to a diffuse pattern, M to a medium sharp pattern and S to a sharp diffraction pattern. Small crystallites in the oxide film give a diffuse pattern. The letter O refers to a pattern which shows arcs or spots and indicate that certain of the planes in the crystal are not randomly distributed but occur at definite angles to the surface or to the electron beam.

The thickness of the oxide film for each time and temperature con-

dition has not been determined for this diagram. In general the thickness is an exponential function of the temperature and a square root function of the time at a given temperature. The diagram is constructed as follows: The specimen is heated to a definite temperature in the vacuum of the camera, which is of the order of 10^{-5} mm. of oxygen pressure. A preliminary diffraction pattern is obtained of the material in the vacuum at the given temperature. Oxygen is added to a pressure of 1 mm. for 1 minute. The system is now rapidly evacuated and a second photograph obtained. Oxygen is again added for

four more minutes and the system evacuated. A third pattern is taken. In this manner the time dependence can be studied at a given temperature. A new specimen is used for each temperature.

An analysis of Figure 3 shows that $\gamma\text{-Fe}_2\text{O}_3$ is the low temperature oxide. Above 225°C . the oxides Fe_3O_4 and $\alpha\text{-Fe}_2\text{O}_3$ are observed. For long periods of oxidation $\alpha\text{-Fe}_2\text{O}_3$ is formed in the range of 250 to 500°C .

For thin films a transformation is observed between Fe_3O_4 and FeO at about 450°C . For thicker films this transformation is observed at 550°C . This latter figure is in reasonable agreement with the data given for the iron oxygen system.

The existence diagram for the dry

oxidation of electrodeposited chromium is shown in Figure 4. The structure Cr_2O_3 (chromic oxide) is found over the complete temperature range. However, the character of the pattern is changed as the temperature is raised. At low temperatures a diffuse pattern is observed while at high temperatures a sharp pattern is found. This indicates a pronounced growth in size of the crystallites in the oxide film. In general as the oxide film thickens the crystallites in the film also grow.

Comparison of Figure 3 with Figure 4 indicates that the oxides formed on iron are four in number while only one is found on chromium. Cooling and heating the iron sample would involve several transformations between the oxide struc-

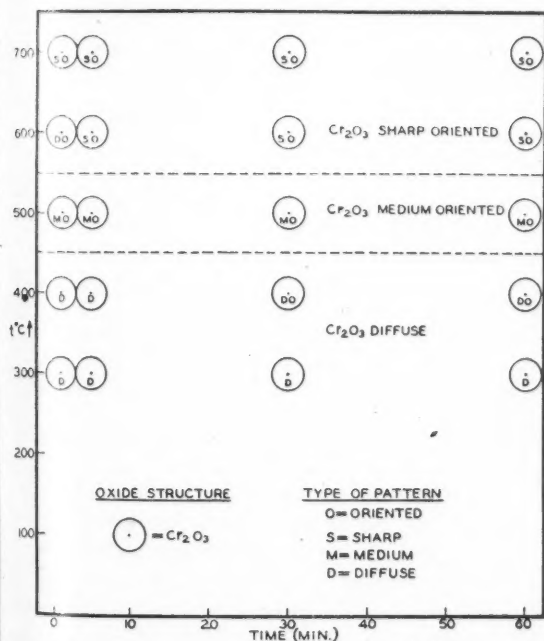


Figure 4—Oxide films on chromium, 1 mm oxygen. Various times and temperatures.

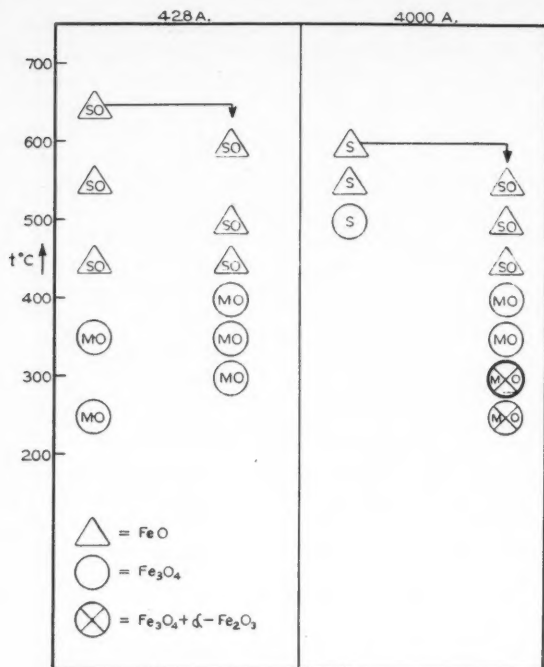


Figure 5—Heat treatment on iron oxide films of known thickness.

tures. Transformations are also occurring as the oxide film grows at a constant temperature. To date, the effect of these transformations upon the secondary structure of the oxide film has not been determined. In general, it is felt that crystal structure transformations are probably detrimental to the protective nature of the film. Chromium is normally considered protective because of the formation of the oxide Cr_2O_3 . The existence diagram shows this to be an extremely stable material from a crystal structure point of view.

b. Heating and Cooling Experiments

To study the details of the transformations in the time-temperature diagram it is of considerable interest to carry out experiments on surface

oxides of various thickness as a function of the temperature. Figure 5 shows two experiments of this type. An oxide film of approximately 428 angstroms is formed at 250° C. Film thickness is estimated by comparison with vacuum microbalance experiments,^{3,4} on the same material under identical conditions of time and temperature. A second film of approximately 4000 angstroms was formed at 500° C. The two specimens are heated to a temperature above their transformation point and then cooled. In the case of the 428 angstrom film the transformation occurred at slightly below 450° C. both in heating and cooling. The thicker film transformed between 500 and 550° C. on heating

and slightly below 450° C. on cooling. There appears to be a lag in the transformation temperature in the cooling operation for the thick film. The results are in good agreement with the predictions of the existence diagram.

c. Effect of Various Gas Atmospheres on Structures Observed After Cooling

Another type of experiment which has proved very useful is the study of the heating and cooling of surface oxide films in various gas atmospheres including oxygen, air, hydrogen, vacuum, etc. Table III is a summary of results on the oxide films formed on iron at 700° C. and 1 mm. of O₂ pressure for 60 minutes of time and then cooled in vacuo,

TABLE III.

Oxide Films Formed on Fe at 700° C and 1 mm O₂ for 60 Min. Cooling in Vacuo, O₂ and H₂

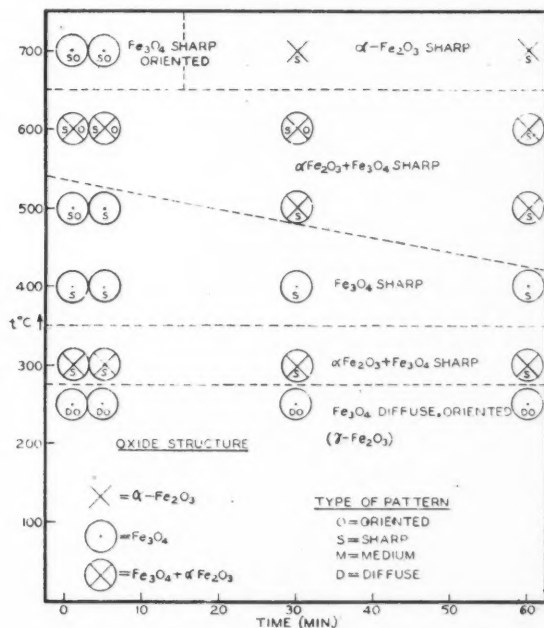
Treatment	Temp. °C.	Pattern
Cooling in Vacuo....	700 25	FeO S.O.* Fe ₃ O ₄ S
Cooling in 1 mm O ₂ .	700 25	FeO S.O. α-Fe ₂ O ₃ , Fe ₃ O ₄ S
Cooling in H ₂	700 25	FeO S.O. Fe, Fe ₃ O ₄ S

*S, Sharp

O, Oriented.

oxygen and hydrogen. Cooling in vacuo gives a structure of Fe₃O₄. A sharp pattern is observed. Cooling in 1 mm. of O₂ gives a sharp pattern of both α-Fe₂O₃ and Fe₃O₄ with the former in the predominant amount. Cooling in hydrogen produces a

Figure 6—Oxide film on mild steel at 1 mm oxygen. Various times and temperatures.



mixture of Fe and Fe_3O_4 with a sharp pattern. These results show the importance of studying the chemical reaction under the proper conditions of temperature. The specimen cooled in oxygen shows continued oxidation while the specimen cooled in hydrogen shows that reduction of the oxide has occurred. The specimen cooled in vacuum shows the transformation to Fe_3O_4 . The final transformation to $\gamma\text{-Fe}_2\text{O}_3$ occurs only after long aging at temperatures below its transformation point.

d. Effect of Alloying Elements

The alloying elements and even the impurities markedly affect the

existence regions for the several oxides of iron. Let us consider a mild steel with the following analyses: 0.18C, 0.028S, 0.030P, 0.32Mn and 0.05Si. The existence chart for this material is shown in Figure 6. The presence of these added materials has a decided effect upon the existence regions of the various oxides of iron. In general these existence regions are elevated to higher temperatures. Although FeO is observed at 500° C. on iron, it does not appear even at 700° C. on mild steel. The strong sensitivity of the iron oxide existence chart to small amounts of alloying elements and to impurities holds promise for many interesting lines of research.

Discussion

Following is a brief discussion of several features of the electron diffraction method which should be considered seriously in applying the method to dry oxidation or corrosion processes.

a. Complexity of the Oxides

Consider the dry oxidation of an alloy containing Fe, Ni and Cr. Not only may the oxides of Fe, Ni and Cr be formed but also solid solutions of these oxides and compound oxides such as the cubic spinels. If water vapor is present in the system, hydrated oxides may form in addition. The lattice parameters of many of the oxides having the same structure differ from one another by one percent or less. This is shown in Table II, which includes the parameters of some of the oxides which might form in the oxidation

reaction. The chemical identification of the particular oxide present on the surface presents a difficult problem because of the limited accuracy of the measurements. The crystal structure may be readily determined but the complete chemical identification is extremely difficult.

b. Effect of Stoichiometric Ratio

The lattice parameters or unit cell dimensions of the oxides are a function of the metal-to-oxygen ratio. This in turn may depend upon how the oxide was formed. This effect has been studied in some detail by Bernard⁶ and Goldschmidt⁷ and may be as large as one percent. This effect is probably important in the study of thin films since the conditions of formation of the oxide may be quite different than in the thick film range.

c. Effect of Surface Preparation

This is very critical, and the influence of the various abrading and cleaning methods must be carefully tested. The influence of oil and grease films is largely eliminated if the study on the dry oxidation process is carried out at high temperature.

d. Studies at High Temperature

The use of high-temperature equipment eliminates some of the difficulties sometimes found in the electron diffraction method. Thus, the charging up of the sample due to the emission of secondary electrons from the impact of the electron beam in the oxide, is eliminated. This is due to the increased conductivity of the oxide at the higher temperatures.

The more important advantage, however, is that the material can be studied in a systematic manner under conditions where the metal is protective or non-protective. It is also possible to avoid crystal transformations, primary and secondary structural transformations and solid phase reactions which may occur as the temperature is changed.

e. Effect of Film Thickness

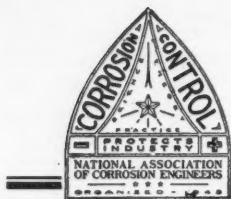
One of the important advantages of the electron diffraction reflection method is that the outside few layers of atoms are studied for the case of a perfectly flat surface. If the material to be studied forms a surface with small crystallites of the order of a few hundred to a thousand angstroms in size projecting into the beam, the electron beam will be able to penetrate all of the material formed in the reaction. The interpretation of the electron diffraction pattern thus depends upon the nature of the surface studied. If the film is below 10-30 angstroms in thickness, there may not be enough material to give a recognizable diffraction pattern. No estimate can be given of the film thickness by electron diffraction methods.

f. Equilibrium

It is sometimes questioned whether conditions present in thin films represent equilibrium conditions. However, a simple analysis would show that, due to the thinness of the film and the readily available sources of metal and reacting gas, equilibrium is rapidly established.

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Topic of the Month

ATMOSPHERIC CORROSION TESTING SITE

By Arba H. Thomas*

IN ITS FIVE-ACRE outdoor laboratory at the northeastern edge of Middletown, Ohio, the Research Laboratories of Armco Steel Corporation are actively engaged in a systematic study of the effects of weather on the corrosion of metals. At present there are eight rows of exposure racks with four racks to a row. The racks consist of galvanized pipe set in concrete and are so situated that no test piece is nearer than 100 feet to the closest part of the fence surrounding the area.

Corrosion samples are mounted by means of porcelain insulators on Type 302 stainless steel frames. Type 303 machine screws are used to fasten insulators to the frames. The frames face south and are inclined at 30° from the horizontal. More than 6500 individual test specimens of various metals, coated (metallic and organic coatings), and uncoated are currently under observation in the mild industrial at-

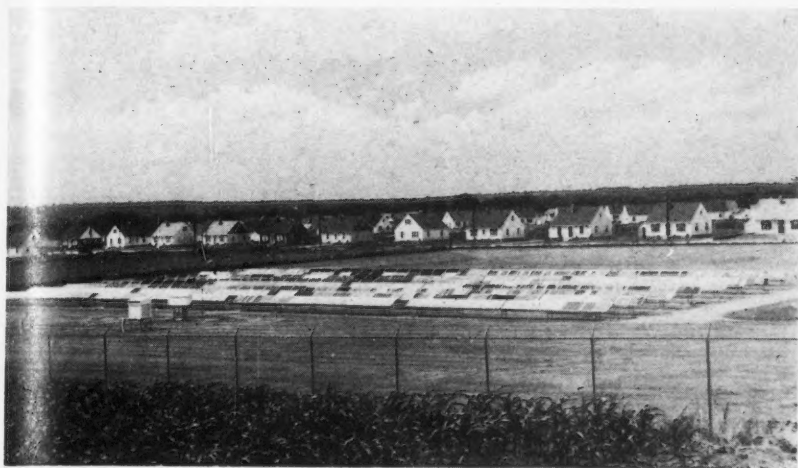
mosphere of this locale. Existing facilities are adequate for the simultaneous exposure of 19,200 4-inch by 6-inch specimens.

One of the most interesting as well as most important features of this proving ground for metals and finishes is its variety of weather instruments. Continuous records are kept of the various factors which may influence atmospheric corrosion.

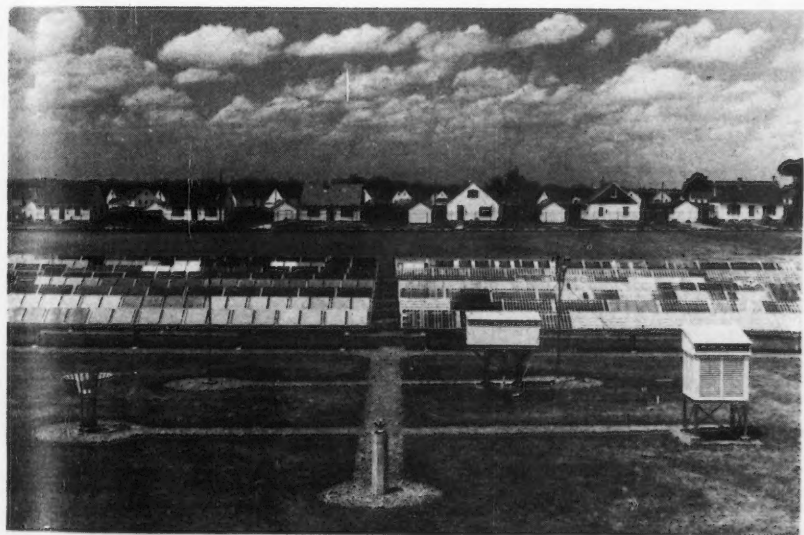
Instruments within the enclosure automatically measure and record air temperature, relative humidity, radiation from the sun, rainfall, wind direction and wind velocity as well as the actual specimen temperatures for a number of materials.

During the past two and one-half years significant data have been gathered in this field laboratory relating to actual effects of day-to-day variations in weather conditions with the behavior of metals. It is hoped that many more basic factors resulting from weather variables will be revealed as the work goes on.

* Chief Chemist, Research Laboratories, Armco Steel Corp., Middletown, Ohio.



General view of atmospheric corrosion test yard.



Close up of test yard, weather instruments shown in foreground.

A Billion-Dollar Objective

To Management Members
Of National Association of Corrosion Engineers.

Gentlemen:

A practical technique that will economically retard, control or stop underground corrosion is a boon to industry. Corrosion is an electro-chemical action of Nature which attacks the metal in most industrial plants. Its ravages may weaken structures and cause accidents. It entails costly plant repairs or replacements. It may cause expensive commodities to leak and to damage property or endanger persons. It may interrupt production or service, thereby reducing income and discommoding customers. Such events usually bring public ill-will, customer ill-will, lawsuits or other contingent losses.

Underground corrosion attacks gas, oil and water pipelines, communications, power and signal cables, rail track systems, tanks and other metallic plant buried in or contacted by moist soil or water. The annual total loss to American industry due to repair and replacement of such structures plus the costs of lost commodities, lost income and contingent losses caused by underground corrosion is estimated to be in the order of \$1,000,000,000.

The modern technique, Cathodic Protection, based on a simple principle known for a century, is an electro-chemical action that combats underground corrosion by beating Nature at her own game. Its application, effectiveness, first cost, continued operating expense and payout in each case depend on local conditions. These features can be determined by qualified corrosion engineers, but the understanding and support of management is needed before its full value to industry can be realized.

With almost 1,000,000 miles of buried pipe, 425,000 miles of railroads and railways, and 167,000 miles of buried cables in our nation*, the possible value of Cathodic Protection is great indeed. That is why eight industry associations, two nationwide communications companies and an engineering society† have formed a joint committee to inform management about it, to foster needed cooperation among operators in applying it, and to aid the solution of its technical problems.

This, the first bulletin prepared by the new Correlating Committee on Cathodic Protection†, is written in layman's language and aimed especially to inform management about this new technique which can curb a staggering economic loss to industry. I commend it to your personal attention.

J. L. LaQue

President, National Association of
Corrosion Engineers

* See detail at end of bulletin.

† See list of sponsor organizations and committee personnel at end of bulletin.

Management Information

on

CATHODIC PROTECTION OF BURIED METALLIC STRUCTURES AGAINST CORROSION

Bulletin 1 prepared by Correlating Committee on Cathodic Protection

CORROSION of buried plant and its contingent losses are costing American industry about a billion dollars per year. Much of this loss can be stopped by proper preventive measures.

These enormous losses and the problems of preventing them are shared in different form and degree by all operators of water, gas and oil lines, communications, signal and power cables, rail tracks, tanks, equipment foundations and other metallic structures buried or in contact with the soil or water.

Corrosion of buried structures is simply a chemical attack by Nature which attempts to revert refined metals to their original form as ores or compounds. This chemical attack always goes hand-in-hand with a flow of electric current from the metal. In most cases a chemical attack causes the current flow but, conversely, a flow of impressed current from metal into soil causes chemical attack. If such current out-flow can be prevented, corrosion cannot occur.

Regardless of whether the attack initiates the current flow or vice versa, the corrosion damage is physically similar; and a current out-flow

of one ampere in one year accompanies a loss of as much as 20 pounds of iron or steel, or 70 pounds of lead.

Corrosion prevention properly starts with the design of structures and equipment, including the selection and placement of materials—in particular avoiding the contact of dissimilar metals—so as to minimize corrosion possibilities. During plant construction and subsequent operation, much corrosion can be prevented by avoiding the disposal of waste matter where it may unnecessarily pollute the soil in or near the plant. In concentrated operating areas, effective surface drainage will minimize the likelihood of soil pollution.

The attention of industry was directed, even before 1900, to the corrosion of buried pipe and cable near electrified street-railway tracks by the currents which "strayed" into these structures from the rails. The pipes and cables were corroded where these currents left them via the soil enroute back to the current source. This type of corrosion is called "electrolysis."

Joint engineering committees in many metropolitan areas, through a

fine spirit of cooperation, have effectively minimized the damage due to stray-current electrolysis. The customary technique is to keep the stray currents as low as possible, and to provide continuous metallic paths through which they will flow back to their source.

Though not initially recognized as beneficial, these currents, when strong enough, stopped corrosion where they strayed into the other structures because they prevented the out-flow of the weaker currents attending such corrosion. This electrical counteraction is the basis of the rapidly developing technique of Cathodic Protection.

In numerous areas where transit companies have abandoned electrified tracks, operators of other structures are finding that the removal of the stray railway currents has allowed the weaker currents of natural corrosion to flow unopposed. The Cathodic Protection before provided in various degrees by the stray currents has been removed!

Outside the geographically small metropolitan areas, different problems are presented. Corrosion of buried structures is widespread unless it is prevented. Among the accepted preventive techniques are properly engineered coatings or Cathodic Protection, or a combination of the two.

If a structure could be coated with an impervious and durable layer of electric insulating material, all flow of current to or from the soil would be prevented. Inasmuch as the soil and moisture would be separated from the structure, corrosion could not occur.

Although excellent coatings now

are available that will provide reasonable protection if carefully applied, most of them will deteriorate or become damaged in time. Such coating defects tend to focus corrosive action and hasten structure damage locally.

Early structures were buried bare, and many coatings applied on other structures prior to the last decade have little if any protective value now. To coat or recoat these operating structures—which usually requires that they be uncovered, raised and cleaned—is difficult and expensive, and often impractical.

For reducing corrosion on older structures, or insuring continued protection with newer coatings, the use of Cathodic Protection is indicated. Specifically, this is the technique of impressing inward-flowing currents to counteract, and thus prevent the outward-flowing currents of natural corrosion. Where Cathodic Protection is applicable, it has the special advantage that it can be installed with very little disturbance of the structures.

To apply Cathodic Protection requires continuous supplies of protective current. It requires also, to be buried in suitable ground-beds at appropriate distances from the structure, one or more masses of metal or carbon (called "anodes") through which this current can be introduced into the soil. For this current to serve its purpose as it fans out through the soil and distributes itself along the structure, it must be of sufficient strength or density to enter the structure and counteract the harmful corrosion currents.

Two types of protective current source may be used. Where con-

siderable current is required, it may be obtained from direct-current generators or rectifiers connected by insulated wires positively to the anodes and negatively to the structure. For the introduction of external currents through the soil into the structure, anodes of graphite rod, or of scrap cast-iron or steel are customarily used.

Where less protective current will suffice, anodes can be used which will self-generate the needed current. When masses of magnesium, aluminum or zinc are buried and connected to a steel or lead structure by insulated wires, they will generate current (as in a battery) which will flow through the soil into the structure.

All types of anodes will be corroded by the protective current which they discharge to the soil, and they must be renewed at intervals. However, under favorable conditions these anodes may last several years before replacement is necessary.

Some of the current introduced at the anodes to cathodically protect one structure may enter a neighboring structure and traverse it for a distance while enroute to the protected one. Where this current leaves the neighboring structure and enters the soil, corrosion occurs which is similar to street-railway stray-current electrolysis. It can be prevented in several ways, one of the commonest of which is to connect the neighboring structure to the protected one by a wire "drainage bond" of proper resistance.

Because of this possibility of interaction, any operator planning a Cathodic Protection installation should notify operators of neighbor-

ing buried structures so that all concerned can appraise the interaction problems. Experience shows that these can be dealt with most effectively and satisfactorily through cooperative study and tests by the engineers of the operators involved.

The foregoing paragraph applies to conditions where Cathodic Protection is designed primarily for the structure (or structures) of a single operator. Frequently, however, where reasonably adjacent structures of two (or more) operators are subject to similar corrosion damage, "joint Cathodic Protection systems" can be designed, installed and operated economically to the benefit and satisfaction of all concerned.

The fundamentals of Cathodic Protection are relatively simple, but solution of its technical and economic problems requires a high degree of engineering skill. The harmony in which metropolitan engineers have coordinated their complex electrolysis problems sets the pattern for the cooperation needed to deal with local Cathodic Protection problems in the field. These call for a business judgment by all concerned, and an approach based on mutual appreciation of the obvious equities and resultant benefits.

The use of Cathodic Protection offers widespread opportunities for reducing the enormous losses incident to underground corrosion, and its application requires cordial inter-company relations. Thus it is good business for all managers of buried plant to be generally informed about, and to give sympathetic support to their engineers dealing with, the application of Cathodic Protection.

The basic objective of the eleven nationwide organizations sponsoring this bulletin is to promote better understanding of Cathodic Protection and to foster the needed cooperation among operators of all types of buried structures in its beneficial application. To this end, each organization will promulgate this and later bulletins of the Correlating Committee on Cathodic Protection in its own format to its own members.

The Correlating Committee on Cathodic Protection is preparing three other bulletins. Number Two will define a practical procedure for inter-operator notification. Number Three will assist corrosion engineers in the technical aspects of Cathodic Protection coordination, and Number Four will treat with "joint systems." However, this general committee will refrain from dealing with individual local problems which may develop.

CORRELATING COMMITTEE ON CATHODIC PROTECTION

Chairman: H. H. Anderson, American Petroleum Institute

Secretary: F. E. Dolson, Jr., American Water Works Association

ASSOCIATION OF AMERICAN RAILROADS
R. B. Amaden, Illinois Central Railroad, Chicago, Illinois

A. E. Archambault, New York Central Railroad, New York, N. Y.

AMERICAN GAS ASSOCIATION

Guy Corfield, Southern California Gas Co., Los Angeles, Calif.

F. J. McElhatton, Panhandle Eastern Pipe Line Co., Kansas City, Mo.

AMERICAN PETROLEUM INSTITUTE

H. H. Anderson, Shell Pipe Line Corp., Houston, Texas

L. F. Scherer, The Texas Pipe Line Co., Houston, Texas

AMERICAN PUBLIC WORKS ASSOCIATION

R. J. Kuhn, Consulting Engineer, New Orleans, La.

W. R. LaDue, Bureau of Water & Sewage, Akron, Ohio

AMERICAN WATER WORKS ASSOCIATION

F. E. Dolson, Jr., St. Louis County Water Co., St. Louis, Mo.

A. R. Davis, City Water Department, Austin, Texas

EDISON ELECTRIC INSTITUTE

G. T. Hieronymus, Kansas City Power & Light Co., Kansas City, Mo.

M. W. Ghen, Duquesne Light Co., Pittsburgh, Pa.

(Alternate, C. K. Poarch, Edison Electric Institute, New York, N. Y.)

INTERNATIONAL MUNICIPAL SIGNAL

ASSOCIATION

Frank Smith, Supt. of Fire Alarm, Tulsa, Oklahoma

J. D. Southwell, Supt. of Fire and Police Communications, Beaumont, Texas

U. S. INDEPENDENT TELEPHONE

ASSOCIATION

G. W. Miller, Rochester Telephone Corp., Rochester, N. Y.

G. C. Richert, U. S. Independent Telephone Assn., Washington, D. C.

BELL SYSTEM

K. L. Maurer, Bell Telephone Laboratories, New York, N. Y.

J. M. Standing, American Tel. & Tel. Co., New York, N. Y.

WESTERN UNION TELEGRAPH COMPANY

J. G. Blain, Western Union Telegraph Co., Dallas, Texas

E. A. Cooke, Western Union Telegraph Co., New York, N. Y.

NATIONAL ASSOCIATION OF CORROSION

ENGINEERS

M. C. Miller, Ebasco Services, Inc., New York, N. Y.

O. C. Mudd, Shell Pipe Line Corp., Houston, Texas

MILEAGES OF BURIED STRUCTURES IN THE UNITED STATES

(According to best available estimates)

Pipe	988,000 mi.
Gas Lines	321,000 mi.
Natural Gas	228,500 mi.
Manufactured Gas	71,200
Mixed Gas	18,500
Liquefied Petroleum Gas	2,800
Water Lines	250,000
Oil Lines	150,000
Crude Oil	133,500
Products	16,500
Miscellaneous Oil Country Pipe	267,000*
Steel Track	425,000
Railroads	406,500
Transit Lines	18,500
Metal-Sheathed Cable	167,000
Communications and Signal Systems	92,000
Electric Power Distribution	75,000
TOTAL	1,580,000 mi.

* NOTE: This figure is based on a 17.5-percent sampling of field operations.



NACE News

SOUTH CENTRAL REGION MEETING PROGRAM

The program for the South Central Region meeting, to be held September 20-21, 1948, in the Tulsa Hotel, Tulsa, Okla., has been completed, according to Derk Holsteyn, Chairman of the General Arrangements Committee. The technical program follows:

Sept. 20

Morning session, 10:00 A.M.-12:30 P.M.

Opening Address, Don Good, Texas Pipe Line Co., Tulsa, Okla.

Galvanic Corrosion as Related to Oil and Gas Well Fluids, F. L. LaQué, The International Nickel Co., Inc., New York, N. Y., and President of NACE.

Control of Corrosion in Condensate Wells, D. T. Mac Roberts, United Gas Pipe Line Co., Shreveport, La.

Afternoon session, 1:30 P.M.-5:00 P.M.

Crude Still Overhead System Corrosion, A. F. Blumer, Esso Standard Oil Co., Baton Rouge, La.

Steam Re-boiler Corrosion, W. S. Janssen, Pan-American Refining Corp., Texas City, Texas.

Corrosion Problems in the Manufacture of Sulfuric Acid, T. L. Hart, National Zinc Co., Bartlesville, Okla.

The Microscope as an Aid in Solving Corrosion Problems, H. M. Wilton, The Texas Co., Port Arthur, Texas.
Movie—Melting and Refining of Modern Steels, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Sept. 21.

Morning session, 9:00 A.M.-12:30 P.M.

Symposium on Internal Protection of Sour Crude Storage Tanks, R. L. Bullock, Leader, Interstate Oil Pipe Line Co., Tulsa, Okla.

Preliminary Evaluation of Resinous Coatings, W. R. Smith, Nukem Products Corp., Buffalo, N. Y.

Technical Factors in Testing Pipeline Coatings, M. W. Belson, D. E. Stearns Co., Shreveport, La.

Installation and Performance of Magnesium Ribbon Anodes, H. A. Robinson, Jr., The Dow Chemical Co., Midland, Mich.

Engineering Aspects of Cathodic Protection, E. P. Doremus, Cathodic Protection Service, Houston, Texas.

Afternoon Session, 1:30 P.M.-4:30 P.M.

Electrolysis and Corrosion Experiences on 110 Kv. Underground Transmission Lines, S. E. Trouard, New Orleans Public Service Co., Inc., New Orleans, La.

Mitigation of Corrosion on a City Gas Distribution System, A. D. Simpson, Jr., United Gas Corp., Houston, Texas.

The Value of Backfill with Carbon and Graphite Anodes, J. P. Oliver, National Carbon Co., Cleveland, Ohio.

A business meeting will be held immediately following the last paper to be presented Tuesday afternoon.

Monday evening entertainment has been arranged to include cocktails from 6:30 to 8:00 P.M., followed by a buffet supper, with a dance scheduled to begin at 9:00 P.M.

Arrangements for the two-day meeting were made by the following

Committees: General Arrangements Committee, Derk Holsteyn, Shell Oil Co., Houston, Texas, Chairman; Technical Program Committee, Nathan Schofer, Cities Service Refining Corp., Lake Charles, La., Chairman; and Local Arrangements Committee, J. Campbell Stirling, Stanolind Pipe Line Co., Tulsa, Okla., Chairman. The latter committee prepared the entertainment program.

Registration for the meeting will get under way Sunday evening Sept. 19. The Tulsa Hotel has set aside a block of rooms for the use of NACE members attending the meeting. Reservations should be made directly with the hotel.

NEW CORPORATE AND ASSOCIATE MEMBERS

Following is a list of new Corporate and Associate members who have joined NACE during the period from July 20 to August 16, 1948; bringing to 207 the number of these types of sustaining Association memberships:

	Representative
American Brass Co., The, Waterbury, Conn.	John R. Freeman, Jr.
American Telephone & Telegraph Co., New York, N. Y.	J. M. Standing, Jr.
Canadian Western Natural Gas Co., Ltd., Calgary, Ont., Canada	B. W. Snyder
Celanese Corporation of America, New York, N. Y.	S. B. Roberts
Chanslor-Canfield Midway Oil Co., Los Angeles, Calif.	H. L. Briggs
Continental Oil Company, Ponca City, Okla.	A. C. Wilkinson
Eastern States Petroleum Co., Inc., Houston, Texas	Ewald A. Roesler
General Petroleum Corporation, Los Angeles, Calif.	Turner Smith
Glasfloss Corporation, The, Hicksville, Long Island, N. Y.	W. F. Yahner
Glass Fibers, Inc., Waterville, Ohio	R. W. Capaul
H. M. Harper Co., Chicago, Ill.	Tom Stott
Hercules Powder Co., Wilmington, Del.	R. F. Schultz
Humble Oil & Refining Co., Houston, Texas	H. D. Wilde
Humble Pipe Line Company, Houston, Texas	O. Q. Lomax
Lane-Wells Co., Los Angeles, Calif.	Norman L. Dorn
Lummus Company, The, New York, N. Y.	E. F. Tibbetts
Missouri Pacific Railroad Co., St. Louis, Mo.	R. P. Hart
Monsanto Chemical Co., St. Louis, Mo.	F. L. Whitney
Nukem Products Corporation, Buffalo, N. Y.	John W. Chandler
Philadelphia Electric Co., Philadelphia, Pa.	H. S. Phelps
Philip Carey Manufacturing Co., The, Lockland, Ohio	V. V. Malcolm
Public Service Co. of Northern Illinois, Chicago, Ill.	E. E. Lungren
Southern Alkali Corporation, Corpus Christi, Texas	John R. Polhamus
Spencer Chemical Co., Pittsburg, Kan.	Ralph D. Miller
Stanolind Oil & Gas Co., Tulsa, Okla.	Joseph B. Clark
Tide Water Associated Oil Co., Houston, Texas	Wm. H. Vaughan
Wilcox Oil Company, Tulsa, Okla.	J. F. Nickell
Youngstown Sheet & Tube Co., The, Youngstown, Ohio	Karl L. Feters

Establishing a precedent, the Program Committee of the Shreveport Section has arranged a tentative schedule for the 1948-49 term, running from October of this year through May of next. Action took place during the July 8 meeting of the Section, which was held at the Caddo Hotel and attended by 30 members and guests. The July 8 meeting was highlighted by a technicolor film presented by the International Paper Co., and titled, *The Heritage of Glass*. No meeting of the group was held in August, and it was decided to forego a meeting in September in order that members of the Section could attend the South Central Region meeting scheduled Sept. 20-21 in Tulsa, Okla. The 1948-49 term will get under way in October with a barbecue; the November meeting will consist of visiting the International Paper Co., plant at Springhill, La., and the December session will be highlighted by a follow-up talk by — McGill, of International Paper, on *Corrosion Around a Paper Mill*. G. R. Olson, United Gas Pipe Line Co., and Past President of NACE (1947-48) will prepare a paper on *Pipe Line Corrosion* for the January meeting. A discussion on *Sour Crude* from McCamey is being sought from the Carter Oil Co., for presentation in February, while the Arkansas Natural Gas Co. will be asked to submit a paper for presentation in March. There will be no meeting in April, the time being set aside for attendance at the National Conference and Convention in Cincinnati, Ohio. In May the year's business will be wound up, with election of new officers taking place.

No meeting will be called during June, July or August, 1949.

Effective July 12, 1948, the following officers took over the business of the Shreveport group:

Chairman, T. B. McDonald, United Gas Pipe Line Co.

Vice Chairman and Program Chairman, M. W. Belson, D. E. Stearns Co.

Treasurer W. S. Bradford, Arkansas Louisiana Gas Co.

Secretary of the Section is Pat H. Miller, Texas Eastern Transmission Co.

Corpus Christi Section met July 21 for a dinner meeting. Porter Hart, The Dow Chemical Co., Freeport, Texas, presented an interesting paper on the use of Magnesium Anodes for Protecting the Mineral Water System of Lake Jackson, Texas. The problem concerned mainly the arresting of corrosion of galvanized iron water services tapped to cast iron mains. Mr. Hart used slides to illustrate the various points developed, and an interesting discussion followed presentation.

Another Local Section

Having been advised that their petition for recognition as a Local Section was approved by the North East Regional Division Board of Trustees, the Metropolitan New York Section has called a meeting for September 29, 1948, for purpose of electing officers for the forthcoming year. The meeting will be held at the Building Trades Employers Association, 2 Park Ave., New York. The meeting will commence with a dinner at 6:30 p.m., and the guest speaker will be Frank L. LaQue, of The International Nickel Co., Inc., New York, N. Y., and President of NACE.

GENERAL INTEREST

N. E. Berry, Servel Inc., Evansville, Ind., Technical Program Chairman for the 1949 NACE Conference and Exhibition, to be held at the Netherland Plaza Hotel, Cincinnati, Ohio, April 11, 12, 13, 14, 1949, advises the appointment of symposia chairman and co-chairman is nearing completion and solicitation of technical papers is already under way. Acting as co-chairman of the Technical Program Committee are: A. Wachter, Shell Oil Development Co., Emeryville, Calif., and Mars G. Fontana, The Ohio State University, Columbus. It is expected that the full membership of the symposia committees can be announced in the next edition of *CORROSION*. In the meantime, it is urged that all members interested in presenting papers get in touch with Mr. Berry or any member of the Technical Program Committee. The use of individual members' knowledge and experience shared through this medium increases the knowledge of all.

Paul Bachman, Commercial Solvents Corporation, Terre Haute, Ind., has accepted the Chairmanship of the Editorial Review Committee of NACE. Other members of the Review Committee are A. W. Tracy, American Brass Co., Waterbury, Conn., F. N. Alquist, The Dow Chemical Co., Midland, Mich.; and George Diehlman, National Lead Co., New York, N. Y. The Committee is already functioning, reviewing technical papers for publication in the NACE journal, *CORROSION*.

To facilitate making of arrangements for the Cleveland Symposium on Surface Chemistry, to be held September 25 in Hotel Carter, Cleveland, Ohio, the Arrangements Committee is requesting that those persons desiring to attend make their reservations early. Registration is \$4.00, including luncheon. For those not desiring to attend the luncheon, cost will be \$2.00. Luncheon reservations must be made in advance, and should be forwarded with check to include registration fee to: N. M. Winslow, National Carbon Co., Box 6087, Cleveland, Ohio, who is serving as Chairman of Arrangements. Tickets will be marked with company or individual name, and may be secured at the registration desk at the opening of the symposium. Other members of the Committee include, K. S. Willson, Chairman; R. A. Schaefer, Program Chairman; L. L. Malm, E. H. Ott and B. A. Smith. Previous attendance marks for the Symposium are expected to be broken in view of the diversity of the outstanding program, which was published in the August *CORROSION*.

The motion picture film entitled, *Must it Rust*, is available on loan to Regional or Local Section groups from the American Hot Dip Galvanizers Association, Inc. Those desiring to secure this film for showing at any of their meetings should get in touch with Mr. S. J. Swenson, Secretary, American Hot Dip Galvanizers Association, Inc., 1611 First National Bank Bldg., Pittsburgh, Pa.

The 35th Annual Convention of the American Electroplaters' Society came to a successful conclusion July 1 at Atlantic City, with over 1200 registrants reported. The convention began June 28, and was held in the Convention Hall in the New Jersey resort city. Twenty papers covering the scientific, engineering and economic aspects of electroplating and metal finishing were presented. Society honors were received by several authors, with the Herminie Dorothea Proctor Award of \$100 going to Abner Brenner and Seymour Senderoff of the National Bureau of Standards for their paper, The Helical Contractometer, a New Instrument for the Measurement of Stress in Electrodoposits. The Founders Gold Metal was presented to R. H. Cahan and C. E. McKinnon, E. I. du Pont de Nemours & Co., for the paper, Diaphragm Tanks to Eliminate Roughness in Copper Plating. The next Convention of the Society will take place in Milwaukee next year, the exact date to be announced later.

Hugh W. Baird is the Vice President of the newly established Standard Pipeprotection, Inc., of which George B. McComb is President, and John B. Wilson Secretary Treasurer. All three were formerly associated with the Barrett Division of the Allied Chemical and Dye Corp. Construction on the \$500,000 pipe wrapping and coating plant will begin shortly and be completed by January 1. It will occupy a 20-acre tract at 3000 S. Brentwood Blvd., in St. Louis, Mo. The plant initially will employ some 100 workers. Plans for the future in-

clude doubling of the plant next year, and construction of two other plants in the Southwest. The company has been incorporated under the laws of Delaware, and capitalized at \$1,250,000. The initial plant will contain modern coating and wrapping equipment for the treatment of small diameter steel pipe.

Industrial Corrosion Control, Inc., whose chief service is lining industrial equipment with anti-corrosive coatings, has been incorporated under the direction of R. G. Forsberg, President. Forsberg also serves as President of Penn-Ohio Industrial Sales Co., and was formerly associated with Jesop Steel Co., and Timken Roller Bearing Co. James D. Clokey, Jr., has been named Sales Manager of the Company, with offices in the Empire Bldg., Pittsburg. The plant is located at Neville Island, Pittsburgh.

American Standards Association has become incorporated under the laws of the State of New York, as American Standards Association, Inc.

CORRECTION

In the list of new Corporate and Associate Members of NACE published in the August CORROSION the name of the representative for the Trans-Arabian Pipe Line Co., San Francisco, Calif., should be H. L. Culbertson.

In the supplementary list of new Active Members of the Association published in the July CORROSION, D. W. Kaufmann's name was misspelled. He is with the International Salt Company, -Buffalo, N. Y.

PERSONALS

Samual S. Johnston, Technical Director, Electrolytic Department, Weirton Steel Co., Weirton, W. Va., was elected President of the American Electroplaters' Society during its 35th Annual Convention, held June 28 to July 1, 1948 in Atlantic City, N. J. **A. W. Logozzo**, President of Nutmeg Chrome Corp., Hartford, Conn., was named First Vice President; **W. J. Neill**, General Superintendent, Columbus Metal Products Co., Columbus, Ohio, Second Vice President, **C. F. Nixon**, Director of Process Engineering, Fisher Body, Ternstadt Division, General Motors Corp., Detroit, Mich., Third Vice President; **A. K. Graham**, President of Graham, Crowley & Associated, Inc., was re-elected Executive Secretary, a position he has held since 1945.

W. H. Stewart, Sun Oil Co., Beaumont, Texas, was elected Chairman of the Corrosion Research Project Committee of Natural Gasoline Association of America, **F. A. Prange**, Phillips Petroleum Co., Bartlesville, Okla., was elected Vice Chairman, succeeding **M. E. Holmberg**, of the same company. The new Steering Committee, of which Mr. Stewart is also Chairman, is composed of **F. A. Prange**, Vice Chairman; **T. S. Bacon** and **Walter Rogers** of the Gulf Oil Corp., Houston, Texas; **P. P. Spafford**, Stanolind Oil & Gas Co., Houston, and **T. S. Zapac**, Shell Oil Co., Inc., Houston. All are active members of NACE.

Paul Queneau has been appointed Metallurgical Engineer of The Inter-

national Nickel Co., of Canada, Ltd., and subsidiaries. He has been Superintendent of Research at International's mines and plants at Copper Cliff, Ontario since 1941. In his new position his headquarters will be in New York City. **W. K. Sproule** succeeds Mr. Queneau as Superintendent of Research at Copper Cliff. He was formerly Chief Physicist of the Company's Copper Cliff Research Laboratory.

J. C. Stirling and **E. A. Slade** have been appointed to the Operating Conference of the Stanolind Pipe Line Co., Tulsa, Okla. The Operating Conference is a special advisory group to the Board of Directors of the Company.

Joseph Chini has been named Superintendent of the Foundry Division of the Sperry Gyroscope Co., Great Neck, N. Y. He succeeds **Stanley E. Tims**, resigned.

Howard Kapner has been placed in charge of the new Glass Section of the laboratories of Sam Tour & Co., Inc., 44 Trinity Place, New York, N. Y.

J. W. McAfee, president, Union Electric Co. of Missouri, has been re-elected president of Missouri Assn. of Public Utilities. Other officers re-elected are: (1) First Vice President, **H. B. Newman**, president, Missouri Utility Co., Cape Girardeau; (2) Second Vice President, **R. D. Green**, president, Missouri Public Service Corp., Warrensburg; (3) Third Vice President, **H. R. Munsell**, president, Kansas City Power and Light Co.

NEW PRODUCTS, MATERIALS AND SERVICES

Literature

Micro Metallic Corp., 193 Bradford Street, Brooklyn 7, N. Y., have increased their line of filter assemblies to include filter elements for use at differential pressures of 1000 and 10,000 psi. The high flow capacities characteristic of the porous stainless steel filter material are retained in these units, it is claimed that due to the high strength of the filter material, no change occurs in the filter even under stresses as high as 10,000 pounds per square inch. The filter containers are provided in carbon steel and stainless construction. Filter elements are all stainless. Stainless containers are of sanitary construction, and in most cases are of the quick opening type.

Utilizing the "cold steam" principle, a new pressure washer with a wide range of application in industrial cleaning jobs, has been announced by the D & M Products Co., 4655 Kingswell Ave., Los Angeles 27, Calif. Named the Hydro-Air, the device produces a blast of cold steam that penetrates and cleans without back splash or harm to finish through the medium of a precisely controlled mixture of water and compressed air.

Dow Chemical Co., Midland Mich., announces its latest contribution for the protection of buried metal structures from corrosion by means of cathodic protection. It is a magnesium ribbon anode, which has been developed and tested in the Company's Research Labora-

tories, and will be marketed under the trade name of Galvo-Line. The new anode has a cross section of $\frac{3}{8}$ inch by $\frac{3}{4}$ inch, and contains a centrally located core of iron wire to facilitate making permanent electrical connections and to prevent possible segregation. It is designed primarily for use in high resistivity soils where cast anodes may not be practical because of their low current output under such conditions. The ribbon anodes are said to provide faster, simpler and less expensive installation, and in addition, reduce current requirements to a minimum by offering more uniform distribution and better utilization of currents from the anode. It is claimed that because of the elongated form, the new anode supplies three to seven times as much current per pound of magnesium installed as does conventional cast anodes. Wound and stored on reels, the ribbon anode is available from the manufacturer in lengths of 1000, 2000 and 5000 feet.

Electro Rust-Proofing Corp., Belleville, N. J., has available a booklet on Fighting Corrosion With Corrosion. The bulletin describes the causes of electrolytic corrosion of metal and describes how the cathodic protection battery may be installed to prevent such corrosion. A number of pictures of installations are shown and the whole process of cathodic protection is presented in diagrams and descriptive matter.

Smoke, fumes and other corrosive agents produced by many industrial plants, often make those plants the worst enemies of their own roofs, according to a new, illustrated, 24-page booklet published by The International Nickel Co., Inc. The new booklet, "One Metal Roof . . . For the Life of Your Building," tells how these highly destructive forces can give roofing troubles an earlier start and increase repair bills. Full data on a new, soft-tempered Monel roofing sheet, designed to overcome severe roofing conditions, is presented in non-technical language. This information is part of a general discussion of the qualities required for a lasting roof with a minimum maintenance. Some of the nation's notable buildings having Monel roofs are pictured. Copies are available from The International Nickel Co., Inc., 67 Wall St., New York, N. Y.

Ceilcote Co., Cleveland, Ohio, is offering an acid and alkali-lining material for fume carrying ducts. Distributed under the trade name, Spray Grade, it has a maximum temperature resistance of 300° F. It will bond to wood or metal. Application is by special spray equipment, which builds up a lining of approximately $\frac{1}{8}$ inch in thickness.

Allied Products Co., Chicago, Ill., are marketing Corodex Coil Clean, developed for cleaning lime scale from hot water coil equipped apparatus or hot water tanks of automatic heaters. The material is not strongly acid but is acidic enough to decompose lime scale and produce foam.

It is claimed not to be harmful to metal or hands of user.

Economy Pumps, Inc., Hamilton, Ohio, has introduced a large capacity axial flow pump designed to resist contaminated sea water and other corrosive liquids. The new pumps are especially suited to condenser circulation and other services requiring low cost high speed pumping of large volumes of liquid.

These pumps should find application in the industries where large volumes of cooling water are used and where it is desirable that such cooling water be separated from industrial wastes.

Directly Applied, rust preventive paint requiring no preparation of surface before application, Rustrem, a black paint, seals rusty surfaces and protects metal against exposure to moist or fume laden air. It serves as an ideal base for protective paint according to the claims of its manufacturer, Speco, Inc., 3142 Superior Ave., Cleveland 14, Ohio.

Kano Laboratories, 75 W. Wacker Drive, Chicago 1, Illinois, have developed a new rust preventive, consisting of a thin, clear film, deposited on metal surfaces. Sold under the name of Kano Rustproof, it is applied by cold dipping, spraying or brushing and dries in about 15 minutes to a clear, hard, dry surface.

The material may be removed with any petroleum solvent, although it is not necessary to remove it prior to painting. It is tough, flexible and non-porous and is available in packages from one to 55-gallons.



Corrosion Abstracts

ATMOSPHERIC CORROSION

Maintenance of Metallic Trim at Rockefeller Center. M. Weiss, *Metal Prog.*, 52, No. 5, 833-834 (1947) Nov.

Report on 10 years' experience with metallic trim at Rockefeller Center, N. Y. atmospheric conditions are considered very drastic, and are described, together with the various metals used. Of all the metals, enameled aluminum and cast 24-12 stainless (used for bass-relief sculpture) show highest repellant to atmospheric deposits and corrosion effects. Cast aluminum accumulates adherent soot almost as fast as bare stone and as rapidly loses its luster. The beauty of bronze is fleeting unless a protective lacquer is constantly maintained. Steel metal window frames must be repainted every four years, causing regret that aluminum was not selected. How the various metals were chosen for each application briefly described.
—INCO.

BEARING CORROSION

The Plastic Deformation of Non-Cubic Metals by Heating and Cooling. W. Boas & R. W. K. Honeycombe, *Proc. Roy. Soc.*, (A), 186, No. 1004, 57-71 (1946).

A comparative study of the properties of tin-base and lead-base bearing alloys revealed that after alternate heating and cooling, surface roughening and cracking occurred on the formerly smooth surface of the tin-base bearing, which increased with the number of treatments, whereas the surface of the lead-base bearing remained quite smooth. The phenomenon was found to be due to an inherent property of the alloy or its constituents. In order to make a fundamental study of the phenomenon, specimens of pure metals, relieved of residual stresses set up by previous cold work, were subjected to cyclic thermal treatment between 30 and 150° C. The non-cubic metals, zinc, cadmium, and tin showed signs of plastic

Abbreviations at the end of abstracts indicate source of abstract and contributor; and are as follows:

AER	Aeronautical Review, Institute of Aeronautical Sciences, Inc.
ALL	The Abstract Bulletin, Aluminum Laboratories, Ltd.
AWWA	Journal, American Water Works Association
BLR	Battelle Library Review, Battelle Memorial Institute Library
BNF	Bulletin; British Non-Ferrous Research Association
CALCO	Calco Chemical Division, American Cyanamid Corp.
CE	Chemical Engineering, McGraw Hill Publishing Co.
CEC	Consolidated Edison Co. of New York, Inc.
EW	Electrical World, McGraw Hill Publishing Co.
GPC	General Petroleum Corp. of California
INCO	The International Nickel Co., Inc.
IP	Institute of Petroleum
MA	Metallurgical Abstracts, Institute of Metals, London, Eng.
MR	Metals Review, American Society of Metals
NBS	National Bureau of Standards
RA	Refrigeration Abstracts, American Society of Refrigeration Engineers
RM	Revue de Metallurgie, Paris, France
RPI	Review of Current Literature Relating to the Paint, Colour, Varnish & Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London.
UOP	Universal Oil Products

deformation-slip lines, some evidence of twinning, roughness of the surface, and intensification of grain boundaries—after a small number of cycles, the effect becoming more pronounced the greater the number of cycles. The phenomenon was not observed in lead, which has a cubic crystal structure. Factors which influence the distortion are, (1) duration and number of cycles, temperature, and orientation of crystals, (2) deformation is independent of grain-size, (3) lattice distortions produced by the plastic deformation of the specimen are not removed by the cyclic treatment but remain in the specimen, and, therefore, become more extensive as the number of cycles increases, (4) grain-boundary migration occurs with tin and cadmium but not with zinc; it is dependent on the duration of the cycle and occurs to a much greater extent during the cooling phase of the cycle, (5) slip lines continue through the crystals to the grain boundaries, where they are emphasized. Concluded that the cause of the deformation is the anisotropy of thermal expansion in hexagonal and tetragonal crystal systems, and an estimation was made of the order of magnitude of the stresses set up, based on considerations of the linear boundary element between two crystals. Mention is made of some of the theoretical and practical applications of the phenomenon: the difficulty of obtaining completely strain-free zinc and cadmium at room temp., the failure of certain bearing alloys, and the effect of such stresses superimposed on externally applied stresses, e.g., fatigue and creep conditions.—MA.

CATHODIC PROTECTION

Corrosion: Cathodic Methods of Protection. M. G. Fontana, *Ind. & Eng. Chem.*, 39, No. 8, 93A-94A (1947) Aug.

Briefly describes cathodic methods of protection. Drawing shows cathodic protection of a heat exchanger. The new Alclad 3S, consisting of 3S aluminum tubing with inner lining of 72S alloy, which is anodic to 3S and protects it cathodically from corrosion, extends the use of aluminum tubing in chemical plant process equipment. Laboratory tests and some service experience show that presence of 72S in Alclad 3S will increase the life of aluminum tubing in corrosive water service four to ten times. Example cited.—INCO.

A Magnesium-Anode Installation for Preventing the Corrosion of Lead Cable Sheath. H. A. Robinson & R. L. Featherly, *Corrosion*, 3, 349-357 (1947) July.

Dow Chemical Co. has developed and tested a galvanic magnesium anode for protecting underground lead cable. Results presented. Test installation showed no sign of deterioration after 21 months of service.—MA.

Mechanism of Cathodic Protection.

R. B. Mears, Carnegie-Illinois Steel Corp., *Oil & Gas J.* 46, No. 31, 77+ (1947) Dec. 6.

Following a review of the theories of the mechanism of metallic corrosion and cathodic protection, the question of determining the current density required to give cathodic protection is considered. Methods used to determine the amount of current required to give cathodic protection are: (1) measuring the potential of the buried steel pipeline against a copper-copper sulfate half cell in contact with the ground and then supplying sufficient current to raise the pipe-soil-copper sulfate-copper potential to -0.85 volts, (2) polarization curve break method, (3) bringing the potential of the corroding article at an anodic area to the same potential at some adjacent cathodic or unattached area, (4) methods based on analysis of the corroding solution.

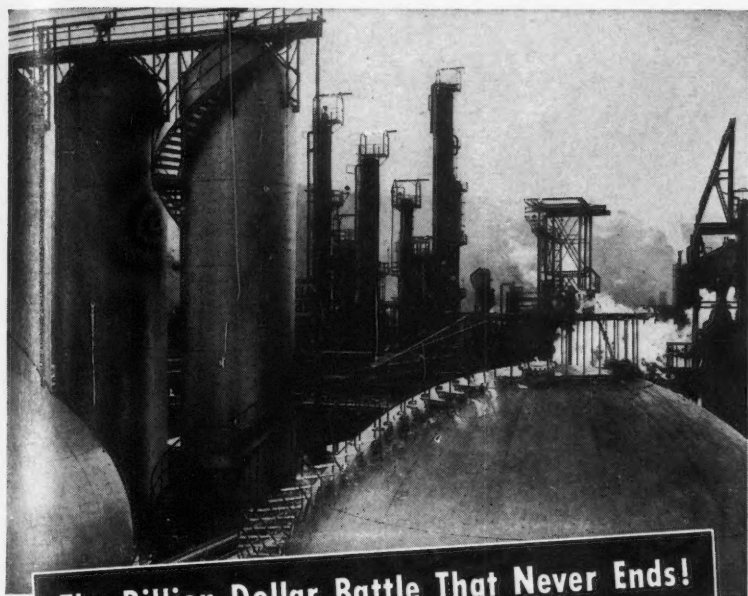
CHEMICAL CORROSION

Intercrystalline Corrosion of Steel by Nitrates. M. Smialowski, paper before Journées Métallurgiques d'Automne—Fall Metallurg. Conf. sponsored by Soc. Française de Métallurgie and Comm. Tech. des états de surface, Paris, (1947) Oct. 6-10.

Influence of various factors on the speed of cracking corrosion of steel by boiling ammonium nitrate was investigated as well as the positive or negative catalytic effect of various compositions (manganese nitrate or phosphoric acid) added to the nitric solution. The study also covered the composition and metallography of the steel as well as the influence of various phases of its surface protection.—INCO.

Correction

In the July, 1948, edition of *Corrosion* on page 24 of the Abstract Section, under "Cast Alloys Stabilized With Columbium or Titanium Alloys," the percentage of columbium should read 0.8—1.0% instead of 8—10 %. Also on page 26, in the abstract "High Yield Strength—Seamless Line Pipe," the content should read 1.40% manganese instead of magnesium.



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Treatment for Prevention of Decay in Stacked Straw. B. F. Stahl & H. L. Smith, Paper before TAPPI, Fibrous Agricultural Residues Comm. (1947) Oct. *Paper Trade J.*, 125, No. 24, 52-54 (1947) Dec. 11.

Losses of stacked straw due to rot and decay caused by mold and fungus are cut by use of sodium pentachlorophenate as a preservative. This fungicide attacked the iron baling wire. Tests on aluminum, iron and galvanized iron wire were made and percent of loss noted. No conclusions as to the wire found most satisfactory are given.—INCO.

Resistance of Sensitized Stainless Steels to Boiling Nitric Acid. R. S. Stewart, Titanium Alloy Mfg. Co., *Metal Prog.*, 52, 971-973 (1947) Dec.

Data shows that use of the Huey [boiling nitric acid (HNO_3)] test to measure susceptibility of stabilized austenitic stainless steel to intergranular attack is unwarranted. Specimens of types 304, 321, and 347 were annealed at 1950° F for 20 mins., water quenched sensitized by being heated at 1250° F for 2 hrs., air cooled then subjected to three 48-hr. periods in boiling HNO_3 solutions containing 35, 45, 55 and 65% acid by weight. The following conclusions were drawn: (1) the corrosion rate of Type 321 (titanium-bearing) decreased markedly as concentration of test medium was lowered, while that of Type 304 (plain 18-8) decreased moderately and Type 347 only slightly, (2) in solutions of 45% boiling HNO_3 and less, there is no appreciable difference in corrosion resistance of the three grades, (3) the titanium/carbon ratio has only a minor effect on corrosion rate, (4) corrosion rate of sensitized plain 18-8 increased with increase in carbon in range 0.05-0.13%, (5) corrosion resistance of all sensitized plain 18-8 steels, even with 0.13% carbon was considerably better in boiling 65% HNO_3 than either of the titanium bearing steels tested, (6) low resistance of sensitized titanium-bearing type to boiling 65% HNO_3 is not due to carbide precipitation. Thus the Huey test is definitely unsuitable for evaluating the tendency toward intergranular corrosion of Type 321 steel. Graphs show corrosion rate of Type 321 (titanium/carbon-5.6, and 11.8), Type 304 (0.07 carbon), and Type 347 (columbium/carbon-12.4) vs. strength of HNO_3 , and corrosion rate of 18-8 plain, vs. carbon content.—INCO.

Influence of Water on the Lubrication of Metals. E. D. Tingle, *Nature*, 160, 710 (1947) Nov. 22.

Results of a study of mechanism of lubrication show that chemical reaction, with the formation of a soap film, is necessary for the effective lubrication of metal surfaces by fatty acids. It is also shown that the presence of water as well as oxygen is necessary for effective lubrication.—BLR.

High-Silicon Irons (vs. Sodium Chloride). W. A. Luce, Duriron Co., Inc., Corrosion Forum, Symp. on Sodium Chloride vs. Construction Materials, *Chem. Eng.*, 54, No. 11, 217-218 (1947) Nov.

Successful applications of Duriron and Durichlor in sodium chloride (NaCl) solutions are briefly mentioned. The former is used in heat exchangers which concentrate hot brine used in packing plants for processing olives and in transportation equipment in production of common salt as high as 280° F. Where appreciable amounts of such contaminants as Cl_2 (or other halogen gases) or hydrochloric acid (HCl) are present, Durichlor gives superior service. This alloy is used for pumps handling a NaCl and HCl solution in chlorination of rubber derivatives and in handling chlorinated brine solutions from cells in an electrolytic Cl_2 -caustic soda plant. Although an occasional case of pitting type attack was noticed, Durichlor was preferred over all other alloys.—INCO.

COATINGS

Tests of Corrosion Resistance of Var-nished Black Plate Food Cans. G. Schikorr, *Korros. u. Metallschultz.*, 20, No. 1, 43-51 (1944); *Chim. et Ind.*, 52, Nos. 1-6, 82 (1944).

Tests were carried out on 2500 cans, filled with meat and vegetables for a year, and secured from many different sources, and also on empty cans. The contents of the filled cans were tested for appearance, smell, taste, acidity, metal content and gas evolution and the empty cans were exposed to the action of distilled water, 2% sodium chloride, 1% citric acid at pH 3 and 1% citric acid at pH 5. Citric acid, (1%) buffered to pH 3 with soda gave rapid results with the empty cans, agreeing well with service tests. The 2% sodium chloride was less satisfactory.—INCO.

Paint Destruction and Metal Corrosion: Microbiological Aspects. R. L. Starkey & J. D. Schenons, *Off. Pub. Bd., Rep. PB. 22*, 473, 59 pp. (1944); NPVL Absts., No. 118, 184 (1946).

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(1) investigation of certain factors concerned with the corrosion of steel and iron in sea water, and (2) influence of micro-organisms and larger fouling organisms on the durability of paints. It is shown that anaerobic corrosion of steel is common and that both iron sulfide and sulfate-reducing bacteria are commonly associated with the corrosion products. Results indicate that the black sulfide is formed by anaerobic corrosion in which the sulfate-reducing bacteria are of major importance. Bacterial attack on common marine paints is evidenced by tests in closed containers where it was found that dissolved oxygen disappearance was not found in sterile samples. Bibliography.

Asphalt as a Protective Material. G. Varlan. *Peint. Pig. Vernis*, 22, No. 11, 343-9 (1946).

Discusses occurrence and properties of asphalt and its suitability as a protective material for roofing, concrete, etc. Action of heat, cold, light, acids, alkalis and exposure to the atmosphere on the asphaltic coating are discussed.—RPI.

Action of Anti-corrosive Pigments in Paints. H. Wagner. *Korros. u. Metallschutz*, 20, 221-4 (1944); *Paint, Oil & Chem. Rev.*, 109, No. 21, 46 (1946).

A critical discussion of the mechanism of action of anti-corrosive pigments. While there is probably some truth in the theory that oxidizing pigments such as red lead and zinc chrome may tend to passivate the surface of metal by forming a protective oxide or chromate film, other factors, such as soap formation by reaction with the medium, appear also to be of importance. Lead oxide is just as good an inhibitive pigment as lead dioxide.—RPI.

Addition of Chromates to Anti-Corrosive Paints. H. Wagner. *Farben Ztg.*, 47, Nos. 27-28, 177-179; *Ibid.*, Nos. 29-30, 187-189 (1942); *Chim. et Ind.*, 50, No. 6, 156D (1943).

Neutral or insoluble chromates have little protective power as anti-corrosives. In the case of basic zinc chromate, the acicular zinc oxide present plays an important part — similarly lead chromes ($\text{PbSO}_4/\text{PbCrO}_4$) are very active primarily by virtue of their needle-shaped particles, while passivation by chromate ion and the formation of soaps play at the most a secondary part. Zinc chrome is effective, independent of the binder, whereas lead chromes need a medium resistant to hydrolysis, etc.

Protection Against Rust in the Construction of Gas and Water Pipes. H. Walther. *Asphalt u. Teer*, 41, No. 37, 435-9; *Ibid.*, No. 38, 449-52; *Ibid.*, No. 39, 461-3 (1941); *Chim. et Ind.*, 47, No. 3, 228D (1942).

Properties of petroleum pitch may be considerably improved by the incorporation of mineral fillers, e.g., whiting or clay. The method of applying petroleum pitches to protect pipes against corrosion is described.—RPI.

Toxicity to Houseflies of Paints Containing DDT. D. Gilmour. *J. Council Sci. & Ind. Res.*, 19, No. 3 (1946); *Paint Mfr.*, 11, No. 4, 132 (1947).

A glossy enamel paint containing 20% and a flat oil paint containing 3-5% DDT, were particularly toxic to houseflies liberated in a box coated with these paints. The toxicity of DDT in paints is a function of the degree of crystallization of the toxin in the films, and an important factor in inducing crystallization appears to be the presence in the paint, prior to application, of sufficient DDT to supersaturate the solvent.—RPI.

Porosity of Sprayed Coatings on Metal. A. Glazunow & L. Jenicek. *Korros. u. Metallschutz*, 20, 27-30 (1944); *Paint, Oil & Chem. Rev.*, 109, No. 20, 40 (1946).

N. C. lacquers were sprayed from a fixed gun on to test panels which were moved at pre-determined speeds ranging from 0.02-0.5 metres per second. Air pressures were varied from 1.5 to 5.5 atms and panel distances from 20 to 30 cm. Porosity was determined by an electrographic method, the test panel being covered with filter paper soaked in $\text{K}_4\text{Fe}(\text{CN})_6$ (potassium ferrocyanide) and brushed with an electrode brush maintained at a fixed potential relative to the panel. This treatment developed blue spots over pores. At low pressures porosity increased at high gun speeds, and at high panel distances films again became porous. Experiments on multi-coat films showed that under conditions giving porous single coats, several coats were necessary to close all pores, so that it was more economical in lacquer to spray in a continuous coating in single strokes than to build it up by overlapping.—RPI.

Coatings and Paints for Protecting Metals Against Corrosion. M. Ballay. *Chim. et Ind.*, 46, No. 2, 133-46 (1941).

Various types of coating are discussed, including painting, different types of plating, phosphating, etc.—RPI.

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Service Tests of Experimental Anti-Fouling Compositions. H. Barnes, M. W. H. Bishop & K. A. Pyefinch, *J. Iron Steel Inst.*, 157, No. 3, 429-446 (1947) Nov.

Account of a number of service tests in which experimental anti-fouling compositions were subjected to varying conditions of service.—BNF.

Discussion of Paper, Chemical Reaction in Metal Protective Paints. W. Beck, *Corrosion*, 3, 593-594 (1947) Nov.

E. J. Dunn found a remarkable drop in the acid number of extracted, dried, linseed-paint films when these contained reactive lead oxide pigments (Aug. issue). The author has measured the pH of the swelling water of the paint film. Results confirm those given by Mr. Dunn.—BLR.

New Paint Medium for Use on Light Metals. *Light Metals* (England) 10, No. 111, 175-176 (1947) Apr.

During the war years, Germany steadily developed a class of organic compounds known as the polyurethanes. It now appears that these materials, when used as paint media, possess an outstandingly good adhesion to light metals. The polyurethanes are resinous materials obtained by reaction between polyisocyanates and various classes of organic compounds containing reactive hydrogen atoms capable of replacement by sodium. Coatings produced by the polyurethane resins can be pigmented in the usual way, the two essential constituents being marketed complete with pigments, solvents and diluents and are mixed immediately before use when reaction begins at once and proceeds rapidly. Films take from 5 to 24 hrs. to dry, according to conditions and the actual constituents employed, but they will stand to hard elastic finishes, elasticity and good adhesion, the coatings are characterized by their excellent durability, resistance to water, chemicals and organic solvents, noninflammability, and excellent electrical characteristics, that is to say, high specific resistance and breakdown voltage.—ALL.

Finishing Clinic. A. G. Gray. *Products Fin.* 10, No. 10, 62-72; *Ibid.* No. 11, 74-85; *Ibid.* No. 12, 54-72 (1946); *Ibid.* 11, No. 1, 56-72; *Ibid.* No. 2, 66-78; *Ibid.* No. 3, 44-60; *Ibid.* No. 4, 74-6 et seq.; No. 5, 50-60; No. 6, 58-60 et seq. (1947); *Chem. Abs.* 40, No. 17, 5265; *Ibid.* No. 21, 6395; *Ibid.* No. 22, 7009 (1946); *Ibid.* 41, No. 4, 9401; *Ibid.* No. 6, 1590; No. 8, 2375; *Ibid.* No. 12, 3733 (1947); cf. Review, 70 (1947).

*The review of metal finishing methods

is continued, subjects discussed including the flame priming of steel, vinyl resin finishes, metal cleaning, fire and health hazards in the finishing room, silicone finishes, finishing zinc and zinc-alloy die castings, primers for use on metals, improving the adhesion of paint to aluminum, cleaning test panels with trichloroethylene, water dip lacquers, importance of film thickness, baking ovens, salt-spray testing, refinishing magnesium gel lacquers, etc.—RPI.

Shipbottom Paints. B. L. Wehmhoff & others, *Off. Pub. Bd., Rep. PB 25*, 574, 233 pp. (1927); *NPVL Absts.*, No. 118, 184 (1946).

The aims of the tests were to develop low-priced anti-corrosive and anti-fouling paints from domestic materials. Four types of paints were considered: varnish paints, hot plastic paints, cold plastic paints, and combination paints. Approximately 1600 paints were tested at Edgewood Arsenal, of which 484 were sent to Beaufort, N. C., for exposure in the harbor. Some study had been started on the determination of the physical characteristics of paint films. The course of further research on the paints was also outlined. The report described the tests and test equipment used. Photographs and tables of test results, formulae of paint mixtures and diagrams of apparatus are shown.—RPI.

Anti-Rust Paints Obtained From German Raw Materials. H. Weise, *TZ. Prakt. Metallbearb.*, 53, Nos. 1-2, & Nos. 3-4 (1943); *Peint. Pig. Vernis*, 19, No. 2, 50 (1943).

General review of synthetic lacquer materials. Ethyl and benzyl cellulose are recommended as media for anti-rust paints.—RPI.

High Frequency Discharge Tests Plastic Lining Leaks. B. W. Whitehorst, Stone & Webster Eng. Corp., *Elec. World*, 129, No. 1, 48 (1948) Jan. 3.

A highly efficient method of testing for continuity of plastic linings for internal surfaces of metallic process vessels is by applying high-frequency discharges generated by a 100-watt universal therapeutic unit, available at about \$80 from most drug and department stores. The discharge electrode should preferably have a rounded end to prevent scratching the lining. When moved slowly above the surface being explored, a characteristic discharge bridges from the electrode and localizes at the defective

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point in the lining. During explorations, the electrode should be maintained from 2 to 3 in. above the surface.—CEC.

Tin Undercoating Improves Rust Resistance of Steel. Anon. *Iron Age*, 160, 45 (1947) Oct. 23.

Use of an 0.00005-in. thick coating on mild steel before painting is recommended. (From report of Tin Res. Inst.).—BLR.

Film Thickness. Anon. *Decorator*, 46, No. 540, 52-3 (1947).

A short survey of the effects of film thickness on the durability, adhesion, moisture penetration and drying time of paint films.—RPI.

CONSTRUCTION MATERIAL

Refractories in Turbine Blades. S. S. Kistler, *CIOS Rept.* Item No. 1, 18, 21, 25, File XXXI-22, 29 pp. (1946).

Visits to the chief ceramic turbine blade plants in Germany reported. Details on the ceramic compositions, properties, preparation of slip and firing are given. Sintered alumina was the strongest material maintaining a tensile strength of 38,000 psi at 1830° F., and 20,000 psi at 2200° F. Compressive strength was 450,000 at room temperature and 70,000 psi at 2200° F. In a centrifugal field of 10,000 gravity, a 3-inch blade was stressed to 4300 lbs. at base. Problem of attachment of ceramic blades is difficult. One manufacturer abandoned use of ceramic blades on rotor and confined attention to ceramic stator and water-cooled rotor blades, although he tried to construct a turbine in which portion normally static rotated while normal rotor was stationary, thus putting the rotating blades under compression instead of tension. Other plants devised a special blade design and mounting method, blades of sintered alumina in the first and only test attaining a speed of 30,000 rpm on a radius of 40 cm before breaking. In an attempt to meet resistance against thermal-shock a composition "Ardostan" with a thermal expansion of one-sixth that of sintered alumina was developed. Bonded silicon carbide blades were also very thermal-shock resistant and incorporation of iron in sintered alumina also gave favorable results. No compositions developed for resistance to sudden temperature changes were as strong as pure sintered alumina, nor did they retain strength as well as to high temperatures. Selection of material depends on relative importance of these two properties. Easiest solution is

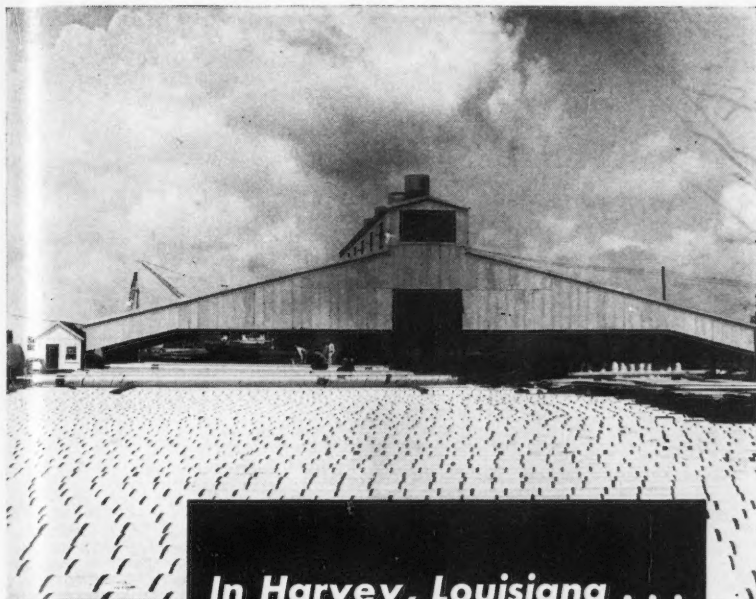
to place blades under compression by centrifugal force. In addition to ceramic blade plants, visits to three plants manufacturing condenser dielectrics are reported. Ceramic products with dielectric constants up to and over 100 are described. Two ceramic bodies with increased magnetic permeability are also described. By using iron power a ceramic permeability of 14 has been obtained and higher are predicted. By combining magnetic permeability dielectric constant and electrical conductivity, articles very useful for the high frequency industry can be produced. Brown Boveri in Switzerland was also visited. A blade made by powder metallurgy in which there is a gradation from pure metal at the bottom to ceramic at the top is produced here. Producers do not hope for much success, however, with ceramic blades because (1) do not believe can withstand repeated thermal shock, and (2) a high damping coefficient is imperative since vibrations become important through synchronization with turbine speed or a multiple of it; this is hard to get with ceramics and mounting the blade in runner is a problem. Use of an 18-8 steel with tantalum and columbium at temperatures of 600° F. in heat recuperators is reported. No information was obtained on the Ritz heat recuperator, of tubular ceramic.—INCO.

Corrosion and the Fluxing of Refractory-Glass Mixtures. J. F. Hyslop, J. Stewart & N. Burns, *Trans. British Ceramic Soc.*, 46, 377-384; discussion, 384-386 (1947) Nov.

A study of refractory-slag cones for two bricks shows that bricks which give a large number of low-viscosity cones below the testing temperature are rapidly attacked, while the bricks which have a long range of viscous cones are relatively resistant to the slag. Describes a new technique for rapid testing. Fusion tests were conducted using soda-lime, lead, and borosilicate glass with a variety of refractories.

Prevention of Corrosion of Iron by Alloying. F. L. LaQue, Paper before ASM, Boston Chapter, (1946) Dec. *Metal Rev.*, 20, No. 3, 35 (1947) Mar.

The manner and extent to which corrosion resistance of iron and steel can be improved by the addition of alloying elements, singly and in combination, is discussed. Specific effects of copper, nickel, chromium (18-8) and molybdenum are explained.—INCO.



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FUNDAMENTALS

Electron-Diffraction Study of Oxide Films on Iron, Cobalt, Nickel, Chromium, and Copper and Alloys at High Temperatures. (Discussion on E. A. Gulbransen and J. W. Hickman's Papers) *Metals Technol.* **14**, No. 4 (1947); *AIMME Tech. Publ.* **2187**, 25-37. Cf. *Met. Abs.*, **14**, 98 (1947).

P. K. Koh refers to the effect of thermal expansion on the measured lattice spacings, and, after replying, Gulbransen reproduces a graph showing the reduced lattice constants of the oxides in iron scale as a function of the oxygen content. R. F. Mehl discusses the orientation and rate of growth of films. In reply to C. G. Goetzel, Gulbransen describes and illustrates the electron-diffraction camera high-temp. furnace. C. H. Samans states that results for the oxidation of stellite in air at 900-1100° C. did not agree with those obtained under the conditions used by Gulbransen and Hickman and reasons for this are discussed. A. R. Bobrowsky questions the sensitivity of the electron-diffraction methods for detecting small percentages of one oxide in the presence of another. In reply to Roger Sutton, Gulbransen states that most of the oxides used would not be expected to decompose at the temp. and pressures concerned. H. S. Avery refers to Fe_3O_4 and the spinels, and emphasizes that many spinel compositions are possible. Gulbransen and Hickman discuss this, and describe electron-microscopic observations of the growth of films. M. L. Fuller refers to the possibility of false values being obtained for lattice spacings owing to the accumulation of positive charge on the specimen, with a resulting deflection of the diffracted electron beams. Gulbransen and Hickman agree with this, but show that the effect could not be responsible for the relatively large lattice spacings which they obtained. Variations in the compositions of different specimens might account for the conflicting lattice spacings. U. R. Evans agrees that departure from stoichiometrical equivalence often occurs. He then describes experiments on the stripping of films from oxidized surfaces; these films were often wrinkled or curved, suggesting the presence of stresses which would affect the lattice spacings. A. G. Quarrell emphasizes that the relatively slight differences between the lattice spacings of different spinels limits the use of electron diffraction methods for identifying substances in the film. He also discusses the protective mechanism.—MA.

Thermogalvanic Effects in Corrosion. H. J. V. Tyrrell, *Met. Treatment*, **14**, No. 52, 243-244+ (1947/48) Winter.

Author comments on the work of Berry and Buffington (*Corrosion*, **3**, 613-631 (1947) Dec.) and on some experiments of his own with silver electrodes. He points out that importance of thermogalvanic corrosion is obscured by the arbitrary convention of taking the temperature coefficient of the normal hydrogen electrode as zero. A short thermodynamic treatment is given.—BNF.

Passivation of Stainless Steels. L. Guilton, *Metaux & Corrosion*, **22**, Nos. 81-89, 47-60, 260-261 (1947) April, May.

A study of methods of passivating 18/8/3 chromium-nickel-molybdenum and 18/10 chromium-manganese steels with respect to attack by sulfuric acid. Stable passivation (for all acid concentrations and at temperatures up to 50° C. with the first steel and up to 100° C. with the second) was achieved either anodically or by immersion in nitric acid; author insists on importance of sensitizing surface before passivating. Potential studies of behavior of the steels in numerous sensitizing and passivating solutions are reported. Effect of working and fabrication before and after passivating was studied.—BNF.

Radioactive Tracers in Friction Studies. J. T. Burwell, Jr., *Nucleonics*, **1**, 38-50 (1947) Dec.

Presents a detailed analysis of new results, experimental techniques, and principles of friction studies with radioactive isotopes. Applications to study of lubricants, metal wear, and other well-known but unexplained phenomena are suggested. 18 refs.—BLR.

Properties of Anodic Aluminum Oxides. II. A study of the Surface Roughness. R. L. Burwell, Jr., P. A. Smudski & T. P. May, Naval Research Lab., *Naval Research Lab. Report C-3093*, 52 pp. (1947) April.

Method developed for determining ratio of true surface area to apparent surface area developed which may be applied to smooth metal foils. Involves the adsorption of ethylene on the foil at -183°C. Method is useful in the study of the preparation of metal surfaces for optimum paint adhesion and in the general study of corrosion phenomena. 18 refs.—INCO.

Optical Study of the Condition of Sand-Blasted Surfaces and the Creation of Testing Techniques (Aluminium, Zinc, Copper, Etc.). F. Canac, *Journées des Etats de Sur-*

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face, Paris, 149-152; Discussion, 152 (1945).

The distribution of diffused light by sand-blasted surfaces of aluminium, zinc, copper, and steels was studied, and the influences of duration of treatment, size of grains, and pressure under which the sand is projected were determined. The apparatus consisted essentially of a luminous source and a photocell mounted on spectrometer arms, with the specimen at the common axis of rotation. Results are given graphically in the form of the logarithm of the observed intensity plotted against angle of observation, and show that the sharp maximum caused by specular reflection decreases markedly as the treatment is continued (5-50 sec.). The forms of the curves are discussed, and it is shown that their lack of angular symmetry is quantitatively related to the character of the indented surface, and equations are developed. The influence of grain dimensions is discussed in terms of the number and size of the indentations produced, and the equation deduced for diffused intensities is experimentally verified. The effects of a decreased projection pressure are parallel to those observed on decreasing the time of treatment.—MA.

Surface Orientation in Corrosion Phenomena. M. Capdecombe, *Journées des Etats de Surface*, Paris, 247-249; discussion, 249-250 (1945).

The conditions for the formation of oriented films of corrosion products on metal surfaces are discussed, and experimental methods of examining the problem, based on the use of the polarizing microscope, are suggested. Typical examples are given. Electrodeposited cadmium (hexagonal in structure) when rubbed dry on a cloth becomes covered with a film of cadmium oxide (CdO) (cubic in structure), which is uniform, but differs in thickness and orientation, over each monocrystalline region. FeS₂ iron sulfide (isotropic), after mechanical polishing, develops an anisotropic film of FeS on all crystal faces except those perpendicular to the ternary axis; the optical axes of the surface are parallel to atomic planes in the crystal. Anodic treatment of cadmium and zinc also produces oriented surface films. Results briefly discussed.—MA.

The Antimony Electrode as a Corrosion Problem. J. Chloupek, *Korros. u. Metallschutz*, 17, No. 1, 25-28 (1941).

The potentials and conductivities of pure antimony electrodes in aerated water

and aqueous salt solutions were measured, and the results show that a larger amount of antimony is dissolved than corresponds with the solubility equilibrium of antimony oxide (Sb₂O₃). Although the reaction determining the potential is not fully understood, this does not interfere with the usefulness of the antimony electrode as an empirical tool for pH determinations and for corrosion research. An X-ray investigation of the corroded antimony surface after use showed the existence of a very thin film of Sb₂O₃ in both the rhombic and cubic crystal forms.—MA.

GENERAL CORROSION

How Long Will Our Metals Last? Carle R. Hayward, *Technol. Rev.*, 50, 96-101+ (1947) Dec.

Believes that the world's supply of metals, definitely not inexhaustible, can be prolonged by international cooperation, aided by conservation and research.—BLR.

Comparison of Electroplated Finishes Under Humidity Tests, Discussions by E. E. Halls, with Author Frank Taylor's answer. *Metallurgia*, 35, No. 207, 137-139 (1947).

Hall comments upon the durability test data published in a previous article by Taylor. He points out that the excellence of the performance of passivated cadmium and passivated chrome; the heavier nickel-tin and nickel coatings were inferior. Chromate passivation is advantageous for zinc as well as cadmium, and the protective value of nickel is enhanced by a final flash coat of chromium. A table of results of W. T. Board K. 110 tests on soft iron with various protective coatings is given. T's reply to H's comments is appended.—MA.

Literature Review on Corrosion of Metals and Materials. *Battelle Memorial Institute Report 1* to AGA, 29 pp. (1947) Feb.

Summarizes results of a literature search on the above subject. Material from 55 articles published during the past 25 years is correlated and presented in concise form. 55 ref.

Report on University Conference (U.S.A.) on Corrosion and Metal Protection. Anon., *Corros. & Matl. Prot.*, 4, No. 4, 10-11 (1947) July-Aug.

Brief abstracts of a number of papers. The papers will be published in full in one volume by Corrosion Publishing Co. 1131 Wolfendale Street, Pittsburgh 12 Pa.—BNF.

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American Gas Association Proceedings. American Gas Association, New York, 552 pp. (1946).

Technical subjects covered include: new developments in industrial furnaces and ovens; anodic protection against corrosion of pipe; production and preparation of coal; partial devolatilization of coal by fluidization; properties of American coals; and oxygen in gas making.—BLR.

Naphthenic Acids. Shell Chemical Manufacturing Co., Booklet, 12 pp. (1947).

Brief notes on the use of naphthenates as driers, rotproofing agents, etc. The preparation of naphthenates is mentioned and the metal contents of aluminum, cobalt, copper, lead and manganese salts of various grades of naphthenic acid are quoted.—CPI.

Mildew and Rot-Resistance of Textiles. P. B. March, *Textile Res. J.*, 17, 597-615 (1947) Nov.

A review. 142 ref.

Making Concrete Resistant to Wear and Corrosion. L. Libberthson, *Ind. & Power*, 53, 98, 114 (1947) Dec.

Shows that deeper and more uniform penetration of fluosilicates for hardening and neutralizing concrete surfaces is obtained when the solution is prepared with surface-active agents.—BLR.

A Review of Factors Affecting the Corrosion of Iron and Steel Used in Building. David W. James-Carrington, *Structural Eng.*, 24, No. 9 449-499 (1946).

The practically most important results of investigations of atmospheric corrosion and its mechanism, as well as combative measures at present available, are effectively reviewed.—MA.

Disadvantage of Dissimilar Metals in Equipment. T. G. Hieronymus, *Corrosion*, 2, 163-164 (1946) Feb.

Designers of industrial equipment need to give more attention to avoidance of dissimilar metals which may set up galvanic cells. Several instances of such corrosion are cited.—MA.

Studies on Corrosion in Great Britain and the U.S.A. During the War (1940-1945). E. Herzog, *Metaux et Corrosion*, 21, No. 251, 92-100 (1946).

Herzog summarizes papers by U. R. Evans and G. D. Bengough on theories of corrosion and protection, read at the conference of the Centre de la Lutte

Contre la Corrosion in Paris in April, 1946.—MA.

Corrosion Control Symposium. Paper before Western Pa. Section, AWWA and the Western Div., Pa. Water Works Operators' Association, Jt. mtg., Pittsburgh, 12-12, (1946) Sept. *Water Works Eng.*, 99, 1177+ (1946) Oct. 2; *Corros. & Matl. Prot.*, 4, No. 2, 24 (1947) March-April.

Deals with the protection against corrosion by formation of protective films, use of Calgon, organic coatings, and chemical treatment.

INHIBITORS

Inhibited Acids for Recovering Tin from Tin Cans. F. C. Mathers, *Proc. Indiana Acad. Sci.*, 54, 112-113 (1945).

An attempt was made to dissolve tin from tin cans with solution of little or no iron. Pieces of tin can 1½ in. sq. were placed in 2N hydrochloric acid and 2N sulfuric acid with additions of arsenious oxide, formaldehyde, quinoline, and glycerol foots, at room temp., and the loss in weight determined after periods of time. Arsenious oxide was very effective, even in hydrochloric acid, but is poisonous and may evolve arsine; formaldehyde and glycerol foots were not very effective, and quinoline is too expensive for common use. It is concluded that, for commercial purposes, none of the inhibitors sufficiently prevented the acid from dissolving the iron.—MA.

INSPECTION

Russians Develop New Method of Gamma Ray Inspection. *Weld. Engr.*, 33, No. 2, 84 (1948) Feb.

Using an original portable device no bigger than a matchbox, invented by Sergei T. Nazarov, Soviet technicians are finding wide applications for gamma rays in testing the welded seams of boilers and other large welded structures. Device consists of a lead-enclosed ampule of radium-mesothorium equipped with a special filter that stops both alpha and beta emanations, permitting only bona fide gamma-rays to pass. Filtering effect makes possible radiographs to depths of 300 mm (12 in.).—INCO.

Measurement of Corrosion. Anon., *Petro.*, 11, No. 2, 48 (1948) Feb.

A simple light reflection meter for the measurement of corrosion consists of an integrating sphere with an aperture at the top, over which the specimen is placed; a photo-electric cell is at the bottom, and a lamp housing low down at



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the side. A beam of light is directed on to the specimen and is reflected on to the photo-electric cell. This is connected to a sensitivity meter which gives relative readings, according to the degree of corrosion. It is hoped to develop this further by means of color filters to estimate corrosion conditions by color changes.

Supersonic Testing of Steel. R. R. Webster, *Yearbook, Amer. Iron & Steel Inst.*, 558-579 (1947).

Properties of sound in steel; methods of introducing sound into steel; methods of application. Prospects for the test in the steel industry. 9 refs.—BNF.

Present State of the Standardization and Methods of Control of Surface Condition in Sweden. Karl Wessel, *Journées des Etats de Surface* (Paris), 144-148; discussion, 148 (1945).

Specifications for surface finish now in force in Sweden described and discussed with special reference to limitations encountered in practice. Author suggests that description of the quality of a surface in terms of maximum depth of irregularities is not sound and may be misleading from the point of view of practical use. As an instrument for assessing surface finish in a general way, the construction and principles of the "theta-metre" are described. This instrument, which is illustrated, depends on the fact that a stylus under a given load penetrates an irregular surface to a greater extent than it penetrates a surface with small irregularities. To ensure the same penetration, the load must be progressively increased as the quality of the surface improves. The load needed for a given small penetration is thus taken as a measure of the quality of the surface for practical purposes.—MA.

A Direct-Reading Electrical Strain Meter. F. C. Widdis, *J. Sci. Instruments*, 24, No. 11, 302-303 (1947).

A direct-reading strain meter constructed from a portable galvanometer is described. The instrument can be used with all types of commercial electrical strain-gauges. Theory of instrument and its sources of error discussed.—MA.

Suggestion Concerning the Use of the "Correlogramme" for the Interpretation of the Characteristics of the Finish of Surfaces. J. R. Womersley & M. R. Hopkins, *Journées des Etats de Surface* (Paris), 135-139; discussion, 139 (1945).

Description of a method for the mathematical analysis of the graphical records obtained from the profilometer type of machine. The results of the analysis may be expressed graphically and reveal the essential periodicity of the irregularities observed without interference from randomly occurring "accidental" phenomena. Such graphs are called "correlation diagrams" (correlogrammes) and may be used to demonstrate similarities between surfaces prepared by similar methods, not readily apparent from the ordinary profilometer record. Method illustrated.—MA.

Electronic Inspection (Detection of Cracks). Vin Zeluff, *Sci. Am.*, 59-61 (1946) Feb.

A new electronic instrument for high-speed production testing for cracks in wires, tubes, and bars is described. A coil is arranged in an electronic oscillating circuit so that it induces eddy currents in the test sample at right angles to its axis. By arranging the frequency so that the current penetration is deeper than the deepest crack, the effect is to provide a short-circuited turn and an effective variable resistance in the coil, which will act like the secondary of a transformer transferring its load to the primary. If the oscillator frequency is then measured, using a crack-free sample to act as a short-circuited turn, the frequency is found to change because of the change in oscillating inductance when a crack in the piece under test enters the coil. The instrument gives indication of cracks from 0.0005 to 0.25 in. deep.—MA.

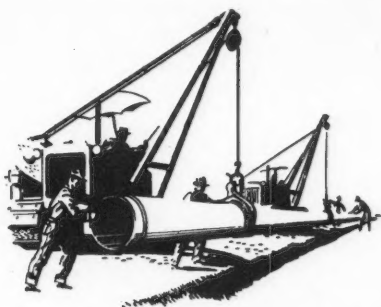
Tubing Without Troubles (Probolog Tester). Vin Zeluff, *Sci. Am.*, 108-110 (1946) Sept.

The "Probolog" is a new electronic instrument which in its present form is used for the routine testing of non-magnetic tubes. It consists of one or more interchangeable probes of different dimensions, a mechanical probe puller synchronized with the chart drive of a recorder, and an electric recorder equipped with a continuous strip chart, but also incorporating a neon indicating lamp. Any defects encountered by the probe upset the balance of a bridge circuit, and the disturbance is transmitted to the recorder by an electronic amplifier.—MH.

Electrical Non-Destructive Testing Materials. G. R. Polgreen & G. M. Tomlin, *Electronic Eng.*, 18, No. 218, 100-105 (1946).

The para- or diamagnetic resistivity of

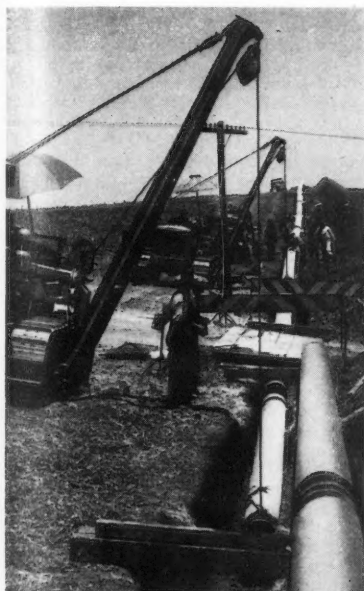
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Portable Ultrasonic Thickness Gage.

Norman G. Branson, *Electronics*, 21, 88-91 (1948) Jan.

Describes instrument by which thickness of empty or full pipes and tanks, or metal sheets, is quickly measured to 1% accuracy. A frequency-modulated oscillator provides an audible indication of plate-current peaks when the oscillator is tuned to fundamental or harmonic thickness resonance with material under test. Indicating dial shows steel thickness directly.—BLR.

METAL FAILURE

Nickel-Span (Nickel-Iron-Titanium Alloys). W. A. Mudge & A. M. Talbot, *Iron Age*, 157, No. 17, 66-70 (1946).

Authors describe the properties of five new nickel-iron-titanium alloys of the Invar type, which are age-hardened after cold working to 35-50% reduction. The alloys may be divided into 3 groups: (1) low-expansion alloys: Nickel-Span "Lo42" (nickel 41.5, titanium 2.4%), Nickel-Span "Lo45" (nickel 45.5, titanium 2.4%), and Nickel-Span "Lo52" (nickel 52, titanium 2.4%); (2) a high-expansivity alloy: Nickel-Span "Hi" (nickel 29, titanium 2.4, chromium 8.5%); and (3) a const.-modulus alloy: Nickel-Span "C" (nickel 42, titanium 2.4, chromium 5.4%). All the alloys contain about 2% of the minor additions and impurities carbon, manganese, silicon, aluminium, phosphorus, and sulphur, the balance being iron. The influence of the alloying elements on the basic iron-nickel system and on the me-

chanical properties of the alloys is discussed in some detail. By compound formation, carbon neutralizes four times its weight of titanium, while titanium neutralizes more than twice its weight of nickel. Increase of titanium content lowers the temp. at which the inflection in the coeff. of expansion/temp. curve occurs in the "Lo" alloys, and moves the thermo-elastic coeff. towards a negative value in the "C" alloy. A similar effect is produced by chromium, but the response to ageing is lowered and the rate of work-hardening increased. Full details are given of the recommended heat-treatments. Softening is accomplished by heating at 1700-1850° F. (926-1010° C.) for 20-90 min., and hardening by heating at 1100-1350° F. (593-732° C.) for 3-24 hrs.; forging and hot rolling are carried out at 2100-2200° F. (1149-1204° C.), with a finishing temp. of 1600-1800° F. (871-982° C.) to refine the grain. The alloys are capable of developing ultimate strengths of up to 200,000 psi. The elastic moduli vary between $21-27 \times 10^6$ psi. The "Lo" and "C" alloys are ferromagnetic at room temp., while the austenitic "Hi" alloy is non-magnetic at all temp. Some information is given with regard to corrosion-resistance.—MA.

Corrosion Resistant Chemical Equipment of Stainless Steel. W. R. Meyer & H. L. Maxwell, Paper before ACS, AICE, & ECS, Sym. on Modern Metal Protection, Cleveland, Sept. 27, 1947, *Steel*, 121, No. 18, 131-132 (1947) Nov. 3.

Nature of stainless steel corrosion and suitable corrosion-resistant alloys discussed. Intergranular corrosion, caused by selective attack of grain boundary material, may be prevented by adding columbium or titanium to the 18-8 steel alloy. Pitting corrosion is exhibited by most austenitic stainless steels but less by molybdenum-modified types. Stress-corrosion cracking may result from exposure of the steel to certain reagents especially chloride solutions. Some chemical agents such as dilute sulfuric acid, sulfuric-nitric or sulfuric-organic acids cause general corrosive attack.

Electroerosion—A New Tool for Metal Working. R. Magidoff, McGraw-Hill News, Moscow Bureau, *Weld. Engr.*, 32, No. 7, 64+ (1947) July.

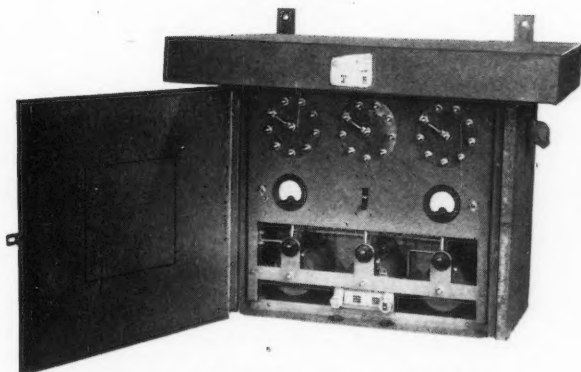
New Soviet method of drilling, slotting, cutting, grinding, or, by reverse action, electroplating by producing a spark discharge (not an arc) which erodes away the surfaces of the workpiece described



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Erosion-Corrosion. W. A. Luce, *Eng. Expt. Sta. News, Ohio State Univ.*, **19**, No. 5, 29-32 (1947) Dec.

Refers to corrosion arising in such conditions as liquids moving at substantial velocities, solids in suspension (slurries), marked turbulence and impingement. Testing equipment described.

PIPE CORROSION

Installation and Protection of Underground Gas Distribution Systems With Pipeline Enamel. P. D. Mellon, *Corrosion*, **2**, No. 2, 124-132 (1946) Feb.; *Paint Notes*, **2**, No. 6, 225 (1947).

Coal-tar enamels are the best protective coating for underground steel pipe at present available. Describes application of this enamel to steel pipes and the problems involved when assembling and welding the pipe. Coating applied on the steel pipe consists of a thin bituminous primer followed by the coal-tar enamel.—CPI.

Pipe Corrosion. Anon. *Balto Eve. Sun* p. 8 (1947) Dec.; *Tech. Sur.* **4**, No. 7 (1948) Jan. 3.

It has been found that pipeline corrosion is chiefly caused by carbon dioxide which forms carbonic acid with water, and also by fatty acids produced by oxidation, etc.

SURFACE TREATMENT

Plating Small Wares. I; Preliminary Polishing-Degreasing-Scale Removal. II; Brassing-Barrel and Basket Plating-Barrel Finishing. R. McNair, *Metal Ind.*, **70**, No. 23, 423-425; No. 25, 464-466 (1947).

Describes the finishing of small articles by barrel polishing and barrel plating in particular, the type of equipment available, abrasive media, preparation of the work, methods of scale removal, and barrel polishing of cast iron steel, and small brass die-castings.—MA.

Modern Mechanical Surface Finishing. M. Manler, *Met. Fin.*, **45**, No. 11, 62-66 (1947) Nov.; *Ibid*, **45**, No. 12, 82-88 (1947) Dec.

Polishing and buffing; polishing wheels; abrasive grain; physical properties of abrasives; selection of proper size grain; glue selection and application; polishing wheel cements, buffing compounds; adjustments required for treating various non-ferrous metals; bibliography.—BNF.

Mechanical and Metallurgical Advantages of Shot Peening. O. J. Horger, *Iron Age*, **155**, No. 13, 100+; *Ibid*, No. 14, 66-76+ (1945).

Critical review of the literature of shot peening and other surface-working treatments. Author refers principally to the treatment of steels, but brief mention is made of light alloys. 48 refs.—MA.

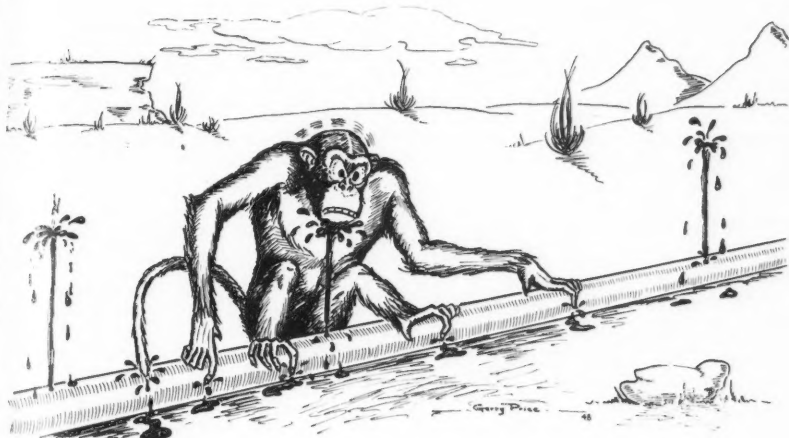
Electrolytic Polishing of Metals. R. W. K. Honeycombe & D. S. Kemsley, *Phys. Metall. Rep. No. 3* (Folio) Serial No. 150, pp. 29 (1946).

Canberra, Australia: Council for Scientific and Industrial Research, Section of Tribophysics.—MA.

Chemical Surface Treatment of Magnesium Alloy Sheet for Spot Welding. W. F. Hess, T. B. Cameron & D. J. Ashcraft, *Weld. J.*, **26**, No. 3, 170-190s (1947).

Suitability of various reagents for preparing magnesium alloys for spot welding investigated. A solution of universal application, containing 10% chromic acid (H_2CrO_4) and 0.05% sodium sulfate (Na_2SO_4) is given particular attention. This solution has a relatively short active life and requires regeneration by addition of sodium sulfate. Analytical control is necessary, and suitable methods are discussed. Material from one supplier responded satisfactorily to a solution of chromic acid without additions, and this was attributed to a trace of sulfate acquired by the surface of the sheet when in the mill. Plain chromic acid solutions differ from other reagents in producing a discontinuous attack, which gives a longer active life to the bath. Results are improved and chromic acid saved if this treatment follows a hot alkaline cleaner.

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Cleaning of Metals. R. Groves, *Metalurgia*, 37, No. 217, 40-42 (1947); *Ibid.*, No. 218, 100-102; *Ibid.*, No. 219, 147-149; (to be continued).

First part deals with choice of cleaning process and agent, second part discusses alkaline cleaners (no exact details of composition given), third part deals with cleaning operations requiring two stages (e.g., for buffed parts to be electroplated, for parts treated with corrosion-protective oils, etc.).—BNF.

The Principles and Scientific Applications of the Electrolytic Polishing of Metals. P. A. Jacquet, *Sheet Metal Inds.*, 24, 2015-2025, 2030 (1947) Oct.

Summarizes results already obtained in the field of scientific applications of electro-polished surfaces. These include: metallography; study of surface properties; study of oxidation and corrosion; X-ray and electron diffraction; suppression of cold emission of metallic surfaces in high vacuum; and study of thin deposits and single crystals. 161 refs.—BLR.

Phosphated Coatings: Their Appearance and Thickness. E. Jaudon, *Metals et Corrosion*, 22, No. 263, 121-124 (1947) July.

Author determines local thickness of different types of phosphated coatings on steel by observing changes in focusing position of a microscope.—BNF.

New Bonderizing Process for Aluminum and Steel. Harold A. Knight, *Matl. & Meth.*, 26, 99-101 (1947) Oct.

Tells how problems encountered in using sheet steel and sheet aluminum on the same production line are lessened by a phosphate treatment which works

equally well on both materials with identical treatments.—BLR.

Use of Carbonized Wood Products in the Protection of Ferrous Metals. A. Lamblotte & J. Bompard, *Metals, Corrosion, Usure*, 16, No. 195, 97-102 (1941); *Chim. et Ind.*, 49, No. 8, 272 (1943).

The compositions of a descaling paste, an anti-corrosive oil, a penetrating oil and a paint remover are given. Recommendations regarding the repainting of steelwork using hard wood tar oil are made.—RPI.

Shot Peening. Fred K. Landecker, *Western Metals*, 5, 15-17 (1947) Sept.

A report on the increased life of metal parts after shot treatment. Results are graphed.—BLR.

Production Line Rustproofing. A. D. Stout, Jr., *Iron Age*, 160, 64-65 (1947) Oct. 30.

Production-line methods at Newark Stove Co. are described. This is the first major installation of the new Banox rustproofing process, developed by Calgon, Inc., Pittsburgh.—BLR.

Recrystallization as a Measurement of Relative Shot Peening Intensities. K. B. Valentine, ASM 1947 Cleveland Mtg., *ASM Preprint* No. 24, 8 pp. (1947).

The phenomena of recrystallization and grain growth of a critically strained, low-carbon steel at subcritical temperature were used as a means of determining the depth of penetration of cold work induced by shot peening. Data indicate that depth of penetration is increased by increase of shot size, shot velocity, and time of peening.—BLR.

Rusting and Painting Troubles Corrected. F. A. Westbrook, *Ind. Fin.*, 23, No. 2, 82-84 (1946).

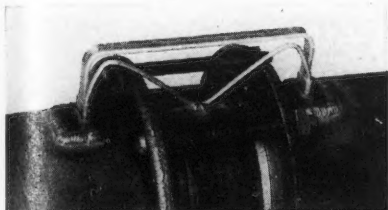
A manufacturer of pressed steel shells for filters had considerable trouble with the finishing owing to the shells being received from the sub-contractors in a rusty and dirty condition. The article explains how the trouble was remedied by use of a rust-preventive oil as a temporary coating.—RPI.

Finishes for Magnesium. R. T. Wood, *Light Metal Age*, 4, No. 12, 14-17+ (1946); *Aluminum & Magnesium*, 3, No. 4, 12-14+ (1947); *Chem. Absts.*, 41, No. 7, 1980; *Ibid.* No. 12, 3733 (1947).

A discussion of the effect of atmospheric conditions on magnesium treat-

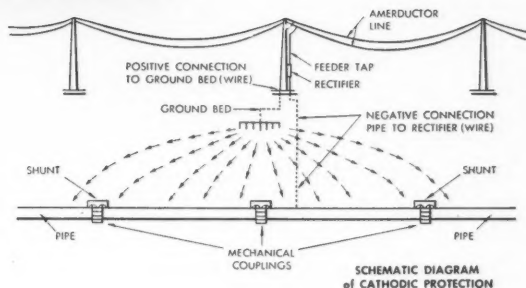
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U-S-S American Pipe Coupling Shunts

ments in preparation for painting, paint systems, and chemical coatings.—RPI.

Paint Removers. L. E. Keuntzel & A. W. Liger, *Iron Age*, **160**, No. 15, 78-83 (1947) Oct. 9.

Paint may be removed from the surface of metals by mechanical methods (scrapping, sanding, burning with a blow torch, etc.) or by solvent methods. The solvent removers include strongly alkaline (water solutions) removers, organic solvents (no water), emulsion-type removers, or combinations of other types. The alkaline removers are used in tanks, the articles to be stripped being suspended in the hot solution until the finish is removed. The other types of removers are usually applied by brushing or flowing. Specifications for paint removers used by the U. S. Army Air Forces during the war emphasized low evaporation, proper viscosity, rinsability, corrosion resistance, nonflammability, and stability. Chlorinated hydrocarbons are good paint removers and with the addition of an activator, such as water, their stripping power is increased further. Acetic acid is also employed as an activator and has a higher ratio of activation than water. Because of the high volatility of the hydrocarbons, wax is frequently used to retard the rate of evaporation. Coupling and wetting agents may be added to keep the wax well blended. Among the materials added to control viscosity, methyl cellulose is considered the best. A series of tests were made by the Wyandotte Laboratories to show the action of a chlorinated hydrocarbon brush-on type stripper. Two sheets of aluminum were used which were given a primer coat of zinc chromate and then coated with lacquer and enamel. The remover began to attack the paint film immediately. The loosened film may be removed with a thin paddle-shaped board or with a scrubbing brush and water. One application of stripper can remove a heavy coat of paint and undercoat but where numerous coats of paint must be removed, several applications are necessary.—ALL.

Shot Peening of Non-Ferrous Metals. H. A. Knight, *Matl. & Meth.*, **26**, No. 5, 83-86 (1947) Nov.

During the war experiments were carried out on shot peening of non-ferrous metals, principally to determine its effect on fatigue strength and on corrosion cracking. For the fatigue strength studies aluminum, magnesium, nickel and various nickel alloys, bronze were used, and the

applied loads included reverse bending, bending, rotating beam and service. For stress-corrosion cracking tests, magnesium and brass were used. Consideration was given to material, hardness, intensity of peening, shot size, shot type and nature of the surface before peening. An example of the results obtained in the fatigue durability test is that of an aluminum alloy nose wheel torque collar. Critical areas and fillets were peened. The test or load was a laboratory fatigue similar to that given in service, applied pneumatically. The average durability of two shot-peened collars was 130% greater than those not peened. In addition to improving fatigue strength, shot peening can greatly improve stress corrosion resistance. Experiments on magnesium alloy AMC-57 SH test strips showed that when stressed and exposed to potassium chromate and sodium chloride, they failed in 120 secs.; when peened, they last 11 days with no cracking or corrosion. J-7E magnesium alloy sheet failed in 9¼ min. when peened it lasted 430 hrs. Shot peening has also been employed to cure porosity in aluminum die casting subjected to pneumatic or hydraulic pressures. One producer reported that as a result of shot peening, die castings on both side in a rotary-type, multitubular machine, 90% of the castings had no leakage, while the remaining 10% had only slight seepage. Manufacturers of aluminum cooking utensils have shot peened for decorative purposes and also to resist corrosive pitting.—ALL.

Electrochemical Surface Treatment of Iron Screening for Use in Reinforced Glass. (In Russian.) V. P. Mashovets & A. P. Obukhov, *J. App. Chem.* (USSR) **20**, No. 3, 219-224 (1947).

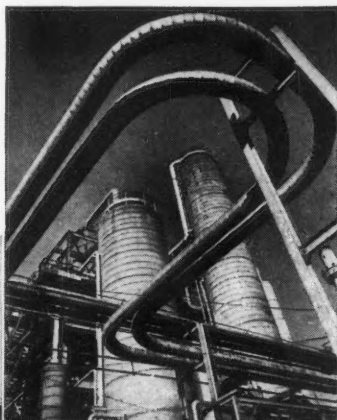
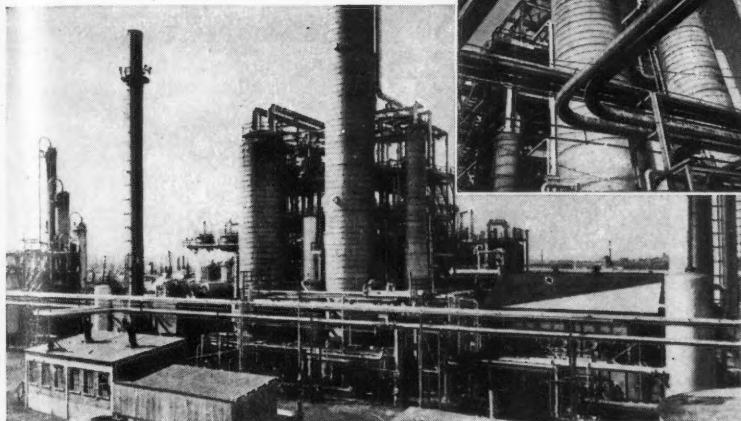
Gives details of a commercial process which has been worked out for electrochemical degreasing, cleaning and degasification of the above.—BLR.

TESTING

A Systematic Scheme for Identifying Corrosion-Resistant Metals. Chester J. Zeck, *Metal Prog.*, **52**, 824+ (1947) Nov.

Qualitative-analysis chart including use of electrographic tests (those where minute quantities of the surface material are removed by applied potential, absorbed on gelatin-coated paper, and identified by spot tests). Construction of electrographic is shown. Analysis scheme also includes other simple and rapid techniques, such as spot and magnetic testing.—BLR.

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Adhesion Testing of Organic Coatings. *Matl. & Meth.*, **26**, 115 (1947) Sept.

Brief descriptions of 20 different test methods.—BLR.

The Accuracy of Corrosion Tests Using Improved Apparatus. (In Russian.) A. S. Afanasev, V. K. Rostovtseva & M. G. Burakova, *Factory Lab. (USSR)*, **13**, 847-850 (1947) July.

Results of a statistical analysis of gravimetric data obtained using the improved apparatus previously described by the first two authors for atmospheric corrosion testing. Considerable improvement in accuracy and reproducibility of results is achieved.—BLR.

Distant Protective Effect of Clad Aluminum-Copper-Magnesium Alloys and a Remarkable Case of Its Absence. F. C. Althof, *Korros. u. Metallschutz*, **16**, 217-228 (1940) *Brit. Absts.*, **BI**, 170 (1947) May.

Duralumin clad with aluminum containing 1% manganese, 0.5% magnesium and 0.5% silicon plus iron was subjected to alternate immersion tests in artificial sea water (I) and 3% aqueous sodium-chlorine (II), using specimens which were non-anodized, anodized, or anodized and scraped to expose the base metal. Specimens aged at room temperature or at 150° for long periods (12 days) were corrosion-resistant, but specimens aged at 150° for short periods (2-18 hrs.) were highly susceptible. Corrosion was more severe in (II), and anodizing had little effect. The cladding protected the base metal at the scratch in (I) but had no effect in (II). The changes from the corrosion-resistant to the susceptible state and vice versa were gradual and variable.—INCO.

Chromate Passivation of Sprayed Zinc Coatings. E. E. Halls, *Metal Treatment*, **14**, 164-168 (1947) Autumn.

Describes corrosion tests on sprayed zinc coatings on steel with particular reference to use of sulfuric acid-sodium dichromate solution.—BLR.

Variable Cycle Alternate Immersion Corrosion Testing Machine. C. H. Mahoney, A. L. Tarr & K. A. Skeie, *ASTM Proc.*, **45**, 719-722 (1945).

Describes and illustrates apparatus for alternately immersing and drying corrosion specimens. Time intervals can be varied at will and each specimen is immersed in a separate beaker of corroding liquid, thus permitting a wide range of tests.—RPI.

Special Performance Testing of Paints. D. E. Star, *Paint Mfr.*, **16**, No. 11, 425-30 (1946); *Ibid*, **17**, No. 1, 24-5 (1947).

The following tests are discussed: accelerating weathering; salt spray and humidity cabinet tests of metal-protective finishes; resistance to grease, fruit juice, alkali, abrasion and impact of refrigerator and kitchen equipment finishes; continuity of coating, adhesion and scorch-resistance tests for canning lacquers; wear-resistance of road-line paints; flame-retardance; permeability and water-absorption of moisture-resistant coatings; biological tests on antifouling, fungicidal and insecticidal paints.—RPI.

UNDERGROUND CORROSION

A Few Comments on Corrosion of Iron in Earth and Mud. P. Nycander & G. Nilsson, *Iva*, **18**, No. 28-30 (Swedish); English abstract page IX (1947). *Corr. & Matl. Prot.*, **4**, No. 4, 24 (1947) July-Aug.

Article on soil corrosion of steel and its prevention.—INCO.

WATER CORROSION

Aluminium Water Pump (for Cooling Automobile Engines). *Modern Metals*, **3**, No. 6, 15 (1947).

Pump described weighs 40% less than a cast-iron one, reduces corrosion troubles in the cooling system, and leads to higher engine efficiency.—MA.

Condensate Return Line Corrosion Control. H. N. Potter, Dearborn Chem. Co., Ltd.; **Some Notes on Corrosion in Condensate Return Lines.** F. L. LaQue, Inso, *Modern Power & Eng.*, **41**, No. 5, 47-48+ (1947) May; *Ibid*, No. 12, 74-48, Dec.

Original article by Potter describes use of inhibitors to mitigate corrosion in condensate return lines. LaQue's notes, provided upon invitation of editor as sequel, present corrosion data from tests at Bayonne, N. J., by Copson, on the behavior of various metals and alloys in distilled water, at various temperatures, with water saturated with various mixtures of carbon dioxide (CO₂) and air. Conclusions were that tin, Inconel and 18-8 stainless were the best materials, in that order. Conclusions were supported by service data from L. F. Collins. LaQue points out the protective nature of the corrosion products, the fact that complete deaeration of boiler water and steam would not completely prevent corrosion if CO₂ were present, but that it is more important for steam to be free of air than of CO₂, and that effects of temperature

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of condensate varies with ratio of CO_2 to air in saturated gas. He points out in conclusion that investigations point the way to corrosion control in condensate handling systems by: (1) elimination or reduction of corrosive agents by feed water treatment and venting of noncondensable gases, (2) use of inhibitors, (3) design and construction of systems to exclude air as far as may be practical and (4) use in critical services of metals and alloys shown to be corrosion resistant under the most unfavorable conditions.—INCO.

Boiler Feed Pump Corrosion? Here's What You Can Do About It. H. L. Ross, Allis-Chalmers Mfg. Co., *Power Generation*, 52, No. 2, 104+ (1948) Feb.

Maintenance problems in high-pressure boiler feed pumps. Causes of corrosion-erosion partly chemical, partly mechanical. Influence of feed water pH value, water velocities, quality of workmanship. Remedies in existing carbon-steel pumps are proper feed water treatment and recirculation. Repair steel casings by welding in stainless steel or building up low-temperature brazing alloy. Describes how 18-8 stainless steel liner is welded in; this must be done at factory and is costly, but helps keep pump going. The use of protective coatings is often successful. When corrosion-erosion of detail parts occurs, it is cheaper to replace with proper materials. For new installations, carbon steel casings are definitely not recommended under any conditions. Cast iron has been satisfactory on lower pressure pumps and 4-6 chromium-steel has been entirely satisfactory and no failures have been reported to date. However, it is difficult to weld in the field and for this reason many pump users have been specifying 18-8 materials. Although more expensive, they are even more resistant to corrosion and are readily repaired in the field by welding.—CEC.

Corrosion Control (of Metal Piping). H. P. Stockwell, *Can. Chem.*, 25, No. 9, 497-502 (1941).

Certain natural Canadian river waters yield a slightly acid effluent after filtration, and lime treatment fails to eliminate all corrosive properties. Comparative exposure tests under controlled conditions have been carried out on cold and hot untreated river water, similar water after various types of treatment, and standard $\frac{3}{4}$ -in. piping of copper, Anaconda brass, wrought iron, copper-bearing iron, galvanized iron, and black iron. The total

exposure period was over 2 years. Results shown graphically. Main conclusions are: (1) for all water treatments copper and brass were much superior to all types of iron piping, (2) copper was superior to brass, (3) galvanized piping showed 10-12 times the resistance of the other ferrous pipes, (4) for the water supply under consideration the lime treatment was the most economical and effective.—MA.

Soluble Silicates for Corrosion Inhibition in the Oil Industry. W. Stericker, Philadelphia Quartz Co., *Corrosion*, 4, 83-92 (1948) Feb.

Discusses addition of sodium silicate to brine to reduce corrosion of steel pipe lines; addition of silicates to cooling (fresh) water system used throughout oil refinery.

Wall-Tube Corrosion in Steam-Generating Equipment Operating Around 1300 Psi. F. B. Straub, *Trans. ASME*, 69, 493-499; discussion, 499-503 (1947) July.

Describes several instances of boiler-tube failures of brittle and non-brittle types. Experience indicates that brittle failure may be caused by the presence of dissolved oxygen in the feedwater in the absence of a suitable oxygen scavenger in the boiler water. The non-brittle type was caused by caustic attack.—BLR.

Brittle Type of Tube Attack. F. G. Straub, Univ. of Ill., Paper before ASME 67th Ann. Mtg., *Combustion*, 18, No. 6, 45 (1946) Dec.; Discussion by R. C. Corey, *Ibid.*, No. 9, 39-42 (1947) Mar.

Instances of boiler-tube failure of the non-brittle and brittle type are discussed. The author concluded that this type of failure is caused principally by dissolved oxygen in the absence of an oxygen scavenger. He described his experiences with the brittle type of tube attack at the Akron plant of Firestone Tire and Rubber Co. and at Fisk Station of Commonwealth Edison Co. In a second instance of brittle-tube failure at Fisk Station, examination of failed portions revealed magnetic oxide with the tube metal reduced in thickness, decarbonized and containing intercrystalline cracks. Micro-examination of the organic matter at the point of failure revealed asbestos fibers. The source of these was the asphalt-asbestos cement with which the interior of the water reservoirs were painted. As a result, the silica content of the boiler water had run as high as 40 ppm. Operation is continuing without serious attack following remedial measures including so-

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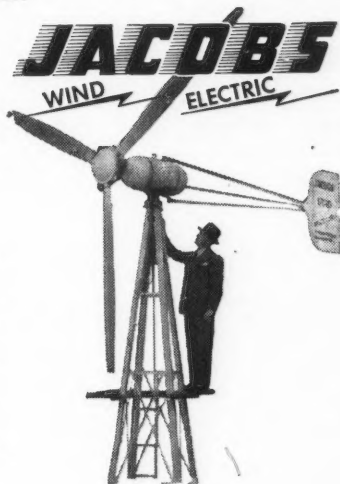
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dium sulfite treatment of feedwater. A third case was that of the corrosion experienced at Mystic Station of the Boston Edison Co., where corrosion occurred as a result of concentration of the boiler water under the iron-oxide sludge on the tube surface. Corrosion was checked by going to coordinated phosphate control in which the salts left behind by evaporation do not contain free sodium hydroxide.—INCO.

Sodium Chloride vs. Construction Materials. *Cem. Eng.*, 54, 211-212+ (1947) Oct.

Part I of a symposium in which typical materials of construction are evaluated for services involving sodium chloride. Includes: "Iron and Steel," by Albert W. Spitz; "Worthite," by W. E. Pratt; "Chemical Porcelain," by John S. Chowning; and "Silicones," by J. A. McHard.—BLR.

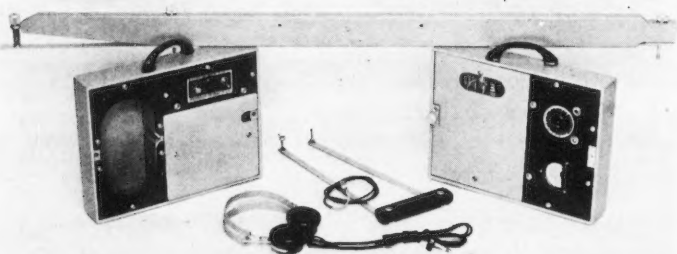
Alloy for Corrosive Jobs. M. G. Fontana, Ohio State Univ., *Bus. Week*, No. 959, 63-64 (1948) Jan. 17.

Carpenter Steel Co. has developed a "super corrosion-resistant" stainless steel that can be wrought, from a casting steel previously produced by Duriron Co. Ma-

terial called Carpenter 20 is described as "half-alloy, half-iron" and contains 29% nickel-20% chromium-3% copper (min.)-2% molybdenum-0.07% carbon, traces silicon and manganese. Dr. Fontana explains role of each alloying element. Material fills gap between ordinary stainless and high-nickel and vanadium-type alloys. Mechanical properties lie in about same range as those of widely available stainless types, and alloy can be forged, welded and formed. Brightest future lies in jobs with H_2SO_4 . Also resists ammonium fluoride brines, fatty acids, hydrofluoric acid, pickling liquors, lactic acid, tanning liquors, vinegar, HNO_3 . It is not recommended for wet bromine, wet iodine, fluorine gas, ferric chloride, muriatic acid, or hydrogen-chloride except in dilute solutions. It complements Durimet 20, which will be used where parts can be cheaply cast, can be used for parts like hoods, ducts, screens, shafts, pipelines and fittings. Potential fields are manufacture of organic chemicals, plastics, rayon, high-octane gasoline, cellophane, pharmaceuticals, food products, fertilizer, and H_2SO_4 , as well as paper manufacture. It will cost four to five times as much as stainless.—INCO.



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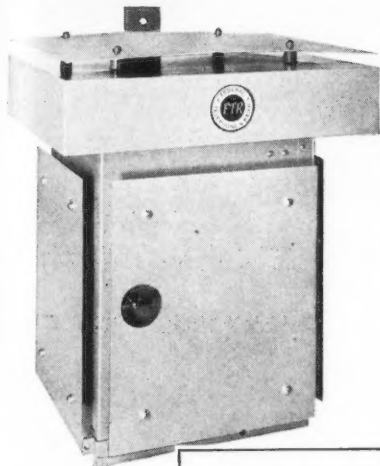
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FTR 5210-B5	2-12	20	115	1	60	None	27"	19 1/2"	14 1/2"	84#
FTR 5211-B5	2-12	40	115	1	60	A	36 1/2"	26 1/2"	20 1/2"	120#
FTR 5239-E5	2-12	50	115	1	60	A-V	36 1/2"	26 1/2"	20 1/2"	200#
FTR 5319-B5	1.5-24	2	115	1	60	A-V	27"	19 1/2"	14 1/2"	36#
FTR 5320-B5	1.5-24	4	115	1	60	A-V	27"	19 1/2"	14 1/2"	60#
FTR 5321-B5	1.5-24	6	115	1	60	A-V	27"	19 1/2"	14 1/2"	65#
FTR 5322-B5	1.5-24	8	115	1	60	A-V	27"	19 1/2"	14 1/2"	80#
FTR 5323-B5	1.5-24	12	115	1	60	A-V	27"	19 1/2"	14 1/2"	85#
FTR 5324-B5	1.5-24	20	115	1	60	A-V	36 1/2"	26 1/2"	20 1/2"	130#
FTR 5325-B5	1.5-24	30	115	1	60	A-V	36 1/2"	26 1/2"	20 1/2"	215#
FTR 5114-B5	10-40	20	230	3	60	A	36 1/2"	26 1/2"	20 1/2"	235#
FTR 5326-CS	3-75	8	115	1	60	A	36 1/2"	26 1/2"	20 1/2"	175#
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Phosphate Treatment of Metals Prior to Painting. H. A. Holden, *J. Oil & Colloid Chem. Assoc.*, 30, No. 321, 61-72 (1947).

Descriptive of the phosphating processes and their industrial applications. Applications to steel and galvanized surfaces are described. RPI.

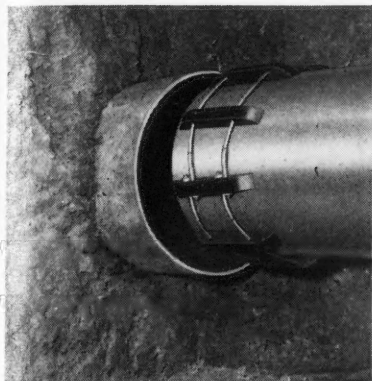
Correct Materials Make Feed Pumps Immune to Corrosion-Erosion. H. L. Ross, *Allis-Chalmers, Power*, 91, No. 7, 464-466 (1947) July.

There are no iron-clad rules for avoiding corrosion-erosion with carbon-steel parts. In general, however, it is advisable to keep feedwater pH above 9.0 or 9.5 by recirculation, or by the addition of caustic, and to eliminate sodium sulfite. It may also help to alternate the pumps in service on the theory that an idle pump builds up a protective film which gives it some protection during the operation. Protective coatings are discussed. A more logical and positive solution is to use materials, such as a 5% chromium (or better) steel. Nickel cast iron (1%) is more than three times as resistant as cast steel, and has not failed because of corrosion-erosion with temperatures up to 400° F. and pressures up to 1200 psi. Other chromium alloys are discussed—many of these require special welding technique to avoid cracks. The 18-8 stainless steel is about five times as resistant as the 4-6% chromium steel, and is easily cast and welded, but difficult to machine. Monel has been found a highly satisfactory impeller material; bronze is satisfactory except for high pH water. For wearing rings, bushings and shaft sleeves, different hardnesses of stainless steel of the 12-14% grade have been highly satisfactory.—CEC.

Electrical Protection of Steel Water Tanks Against Corrosion. R. J. Smith, *Pub. Utilities Commission, Perth, Ont., Eng. Contract Rec.*, 60, No. 5, 92, 94, 96 (1947); *Chem. Absts.*, 41, No. 17 (1947) Sept. 10.

Cathodic protection prevented interior corrosion of an elevated tank for seven years at a cost of about \$5 per year. A rectifier delivers 4 amp. at 27 v. to a stainless steel electrode, 18 ft. long and 1½ in. in diameter, suspended from the tank roof. The electrode has become pitted and will be replaced by a magnesium rod. Less current is required when aluminum or magnesium electrodes are employed and less metal is consumed. A current of 4 ma. per sq. ft. may be required in the case of water of low pH value; protection against Great Lakes water requires only 0.66. Calcium carbonate,

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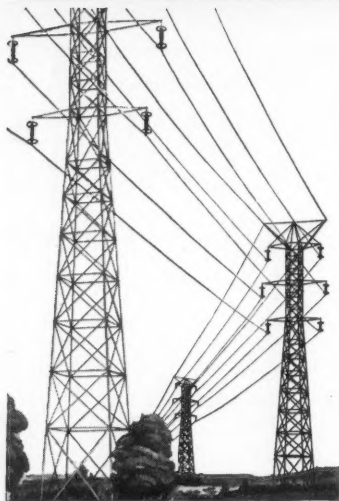
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Corrosion of Boilers by Oxygen Compounds of Sulfur. (In French) A. Bariteau. Publ. by Imprimeries Saint-Gilles, Paris, 50 pp. (1946).

Studies carried out at the Laboratoire of Industrial Heating of the Conservatoire National des Arts et Metiers, on boiler corrosion by sulfur compounds from combustibles are reported. Formation of the attacking element, influence separately and simultaneously of the various constituents of the fumes upon condensation of acid vapors, as well as the importance of the effects of absorption and of catalysis of soots, and finally, research as to methods or processes of preserving heating installations are studied successfully. Apparatuses used in the experiments were: (1) the detector used by Tessier for the experimental part of his thesis for doctor of engineering, Paris 1943 and (2) the hygrometric tester for determining the dewpoint of the fumes from Gouffe, Laure and Prevot (Journal des Usines a Gaz, 1944-45). Results are interpreted so as to arrive at practical ideas for construction and operation of heating installations. Finally, results are explained in the form of an abacus permitting rapid calculation of the dewpoint of the fumes of a given combustible or vice-versa determining composition of a combustible for which the dewpoint has been established.—INCO.

Design Standards for Steel Water Pipes. Russell E. Barnard, *J. AWWA*, 40, 24-30 (1948) Jan.

Presents extensive design data for steel water pipelines from 6 to 36 in. in diameter. 16 ref.—BLR.

Action of Water on Aluminum. H. Lichtenberg, *Korros. u. Metallschutz*, 16, 251-259 (1940); *Britz Absts.*, BI 194 (1947) June.

Corrosion of aluminum in tap water is controlled by the purity of the aluminum and the inorganic constituents present in the water. Chlorides gave an accelerating effect, especially with base-exchange-softened water. A case of corrosion by condensed water in a tubular heat exchanger is described.—INCO.

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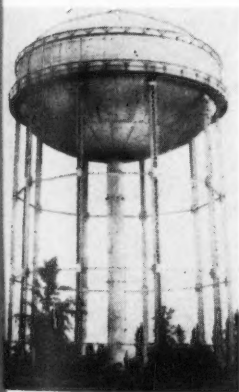
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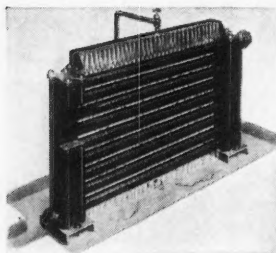
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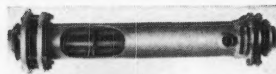
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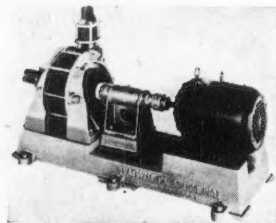
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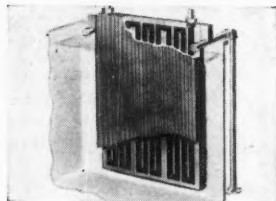
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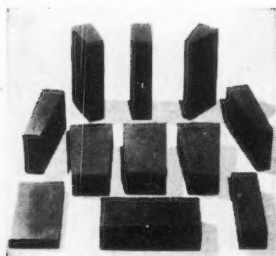
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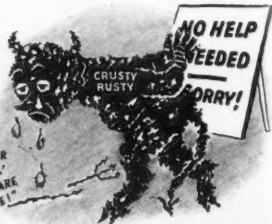
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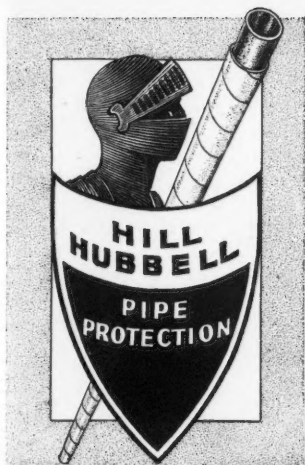
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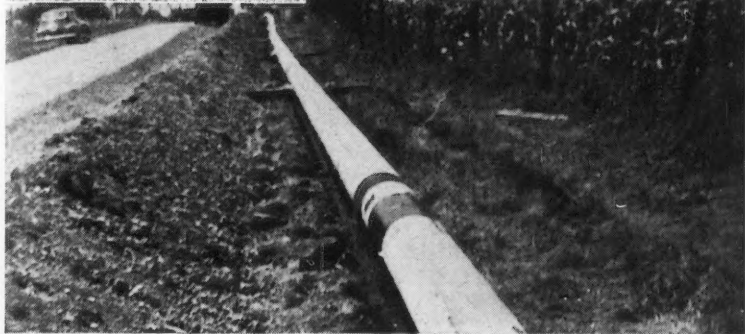




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